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THE WORK OF THE BOAT PARTY

BY

F. S. RUSSELL, D.S.C., B.A., AND A. P. ORR, M.A., B.Sc., A.I.C.

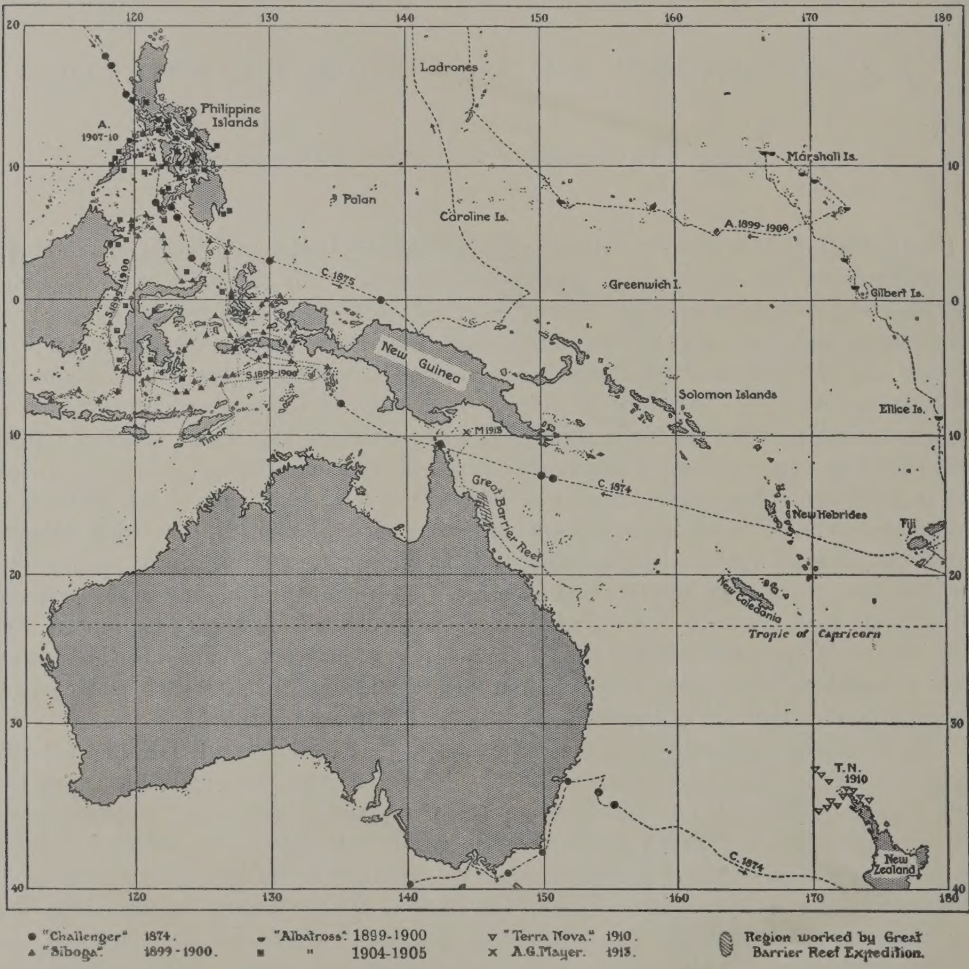
WITH ONE TEXT-FIGURE AND THREE PLATES.

The solution of the many problems connected with life in the sea depends on a thorough understanding of the conditions in the surrounding water. No observations on the living animals and plants of an area can be considered complete if full data are not available on the chemical and physical conditions under which they live. The importance of temperature for the distribution of organisms, for their breeding periods and rate of development, has long been known. The study of salinity as an index to the origin and movements of water masses dates from the birth of the science of oceanography. In all previous expeditions therefore, opportunities to observe temperatures and salinities have not been missed. But it is only in comparatively recent years that the full significance of the presence in small traces of certain chemical substances in the sea has been realized. In North Atlantic waters the study of such limiting nutrient salts as phosphates and nitrates is receiving its due attention. On their presence and abundance the quantity of life in the sea depends, the ultimate food products, the phytoplankton, being limited by their occurrence. The close relation between the seasonal changes in quantity of nutrient salts and the abundance of the phytoplankton crop has been followed for several years, together with such changes in the oxygen content of the water as may be effected by the life therein.

The importance of many plankton organisms as food for larger animals, and directly or indirectly as food for fishes, is now realized. Plankton research has advanced from the early stages of collecting and naming the animals and plants to its present broader aspect. When plankton organisms were first studied in North Atlantic waters, and described by the early naturalists, the possibilities of their quantitative study had not been realized. This work is now in an advanced stage; the work of the systematist in describing and naming all the various species that compose the plankton has been largely completed, the main seasonal changes in abundance are known in outline, and research now centres chiefly on the abundance, life-histories and habits of certain dominant forms and their importance from the economic point of view.

In the Pacific Ocean, plankton research is not so far advanced as in the North Atlantic, which has been studied by workers from the many different countries bordering its seas, to whom a special impetus was provided by the enormous importance of the European fisheries. While a beginning has been made on the quantitative study of plankton by workers at marine biological laboratories along the eastern coasts of the Pacific, especially at the Scripps Institute for Oceanography at La Jolla, our knowledge of the plankton on the western coasts has been gained from the widely separated and relatively scanty collections of visiting expeditions. The same is unfortunately true of our knowledge of the chemical and physical conditions of the sea in these regions.

We reproduce here a chart (Text-fig. 1) of the western half of the Pacific, in which have been inserted the tracks of such vessels engaged in oceanographical research as have


120
130
140
150
160
170
180
20
10
0
10
20
30
40
Ladrones
Philippine Islands
A. 1907-10
Marshall Is.
Palau
Caroline Is.
A. 1899-1900
C. 1875
Greenwich I.
Gilbert Is.
S. 1899-1900
New Guinea
S. 1899-1900
Solomon Islands
Ellice Is.
Timor
M 1913
C. 1874
Great Barrier Reef
New Hebrides
Fiji
New Caledonia
Tropic of Capricorn
T.N. 1910
C. 1874
New Zealand
● "Challenger" 1874.
▲ "Siboga" 1899-1900.
▼ "Albatross" 1899-1900
■ " 1904-1905
▽ "Terra Nova" 1910.
× A.G. Mayer. 1913.
▨ Region worked by Great Barrier Reef Expedition.

TEXT-FIG. 1.

visited those waters, and the positions at which stations were taken. These include H.M.S. "Challenger" in 1874; the U.S. Fish Commission steamer "Albatross" under Prof. Alexander Agassiz in 1899 and again in 1904–5; the Dutch research vessel "Siboga" under Dr. Weber in 1899–1900; and the "Terra Nova" in 1910–11. At the present moment, the Dutch "Snellius" Expedition is operating around the Dutch East Indies, and Prof. Schmidt has just returned from cruising with the "Dana" in Pacific waters.

A glance at the chart, however, shows that most of the collecting has been concentrated around the Dutch East Indies and the Philippine Islands, and emphasizes the almost complete absence of observations from the Barrier Reef region. A few isolated collections have been made, as, for instance, Dr. A. G. Mayer's of the *Medusae* of the Torres Strait, but the plankton, as a whole, has been noticeably ignored, while in the same area the coral reef fauna has attracted the attention of a number of marine biologists.

But observations made by previous expeditions have only been spasmodic, no information being gained on the seasonal changes in the physics, chemistry and biology of the sea-water, nor any conclusions of permanent value drawn. A series of collections of water samples and plankton taken in North Atlantic waters in winter would give a very different picture from similar collections made in summer.

It was one of the aims of this expedition, therefore, to make a detailed study of a particular area throughout a whole year, and a section of the expedition was detailed for work at sea. This boat party consisted of Mr. F. S. Russell (zooplankton), Mr. A. P. Orr (hydrography), Miss S. M. Marshall (phytoplankton) and Mr. J. S. Colman (zooplankton).

For routine collections we had at our disposal a ketch-rigged motor yacht, the "Luana," 39 ft. in length with a draught of 3 ft., fitted with a 26–30 h.p. sleeve-valve Kelvin engine (Plate III). This yacht was owned by Mr. A. C. Wishart, of Brisbane, who, apart from lending the vessel to the expedition, volunteered his own services, thus rendering us a favour for which we cannot be too grateful. Mr. H. C. Vidgen, also of Brisbane, accompanied him, and was an invaluable assistant on board. In addition we had the help of two boat-boys, Harry Mossman and Paul Sexton, from the Anglican Mission at Yarrabah, who undertook the heavy work and rendered much useful assistance.

The expedition was based on Low Isles, a coral reef lying eight miles from the mainland, midway between the coast and the Outer Barrier in latitude 16° 23′ S. and longitude 145° 34′ E. The configuration of this reef was extremely suitable in that it allowed of a safe anchorage in a slight inlet on the northern side, sheltered from the prevalent S.E. trade winds. Only in the worst northerly weather in summer did it become necessary for the vessel to seek the shelter of Port Douglas on the mainland. The lagoon channel inside the Barrier extends for many miles north and south, with a uniformly level bottom rarely exceeding a depth of 20 fathoms. To the west of Low Isles the bottom gradually shelved from the coast to a depth of 10 fathoms, while on the eastern side it deepened from 13 fathoms to a narrow gut just off Batt Reef, where a depth of 21 fathoms was reached.

It was decided that work should be concentrated on some point within easy reach of Low Isles, where conditions would probably be typical of the lagoon channel and a fair depth of water could be found. At this spot weekly observations were to be made of the physical and chemical factors of the sea-water and its plankton content. The position chosen for this weekly station was 3 miles east of Low Isles, almost midway between Low Isles and Batt Reef, where the depth was 17½ fathoms (32 metres) (see Plate II). At this station water samples were collected, and examined for salinity, phosphate, silicate, oxygen content and hydrogen ion concentration ; the temperature and transparency of the water were also noted. Water samples, from which counts were made of the contained microplankton and phytoplankton, were collected for centrifuging, and collections were made with tow-nets of different mesh, for the study and enumeration of the larger plankton organisms. The data thus obtained should lay a foundation for a knowledge of the seasonal cycle of events in tropical waters, lying inside the Barrier, besides providing very complete collections for a study of the planktonic flora and fauna living in these waters.

The vessel at our disposal proved too small and the distances were too great for a regular study of the open ocean waters beyond the Barrier, and occasional trips only could be made. Low Isles was conveniently situated in that it was near Trinity Opening, one of the larger passages which connect the lagoon waters with the ocean outside. A few stations were therefore taken in this opening inside the 100-fathom line to observe the possible intermingling of ocean and coastal waters, and the occurrence of oceanic and neritic species in the plankton.

Observations on the open sea beyond the Barrier could only be made on a few occasions. Most of these were made from the " Merinda " and the " Magneta "—boats which were chartered specially for this work, both considerably larger than the " Luana." By using these vessels it was also possible to compare conditions with those at the station three miles to the east of Low Isles. For a comparison with the Trinity Opening station, and to observe the conditions on the seaward slope of the Barrier, where the bottom shoals from slightly over 20 to several hundred fathoms in about a mile, stations were worked in and outside of Cook's Passage and Papuan Pass. By the kindness of the Navigation Department, a few water samples were taken in the coral sea between Townsville and Willis Island. Unfortunately, rough weather interfered considerably with the taking of the samples.

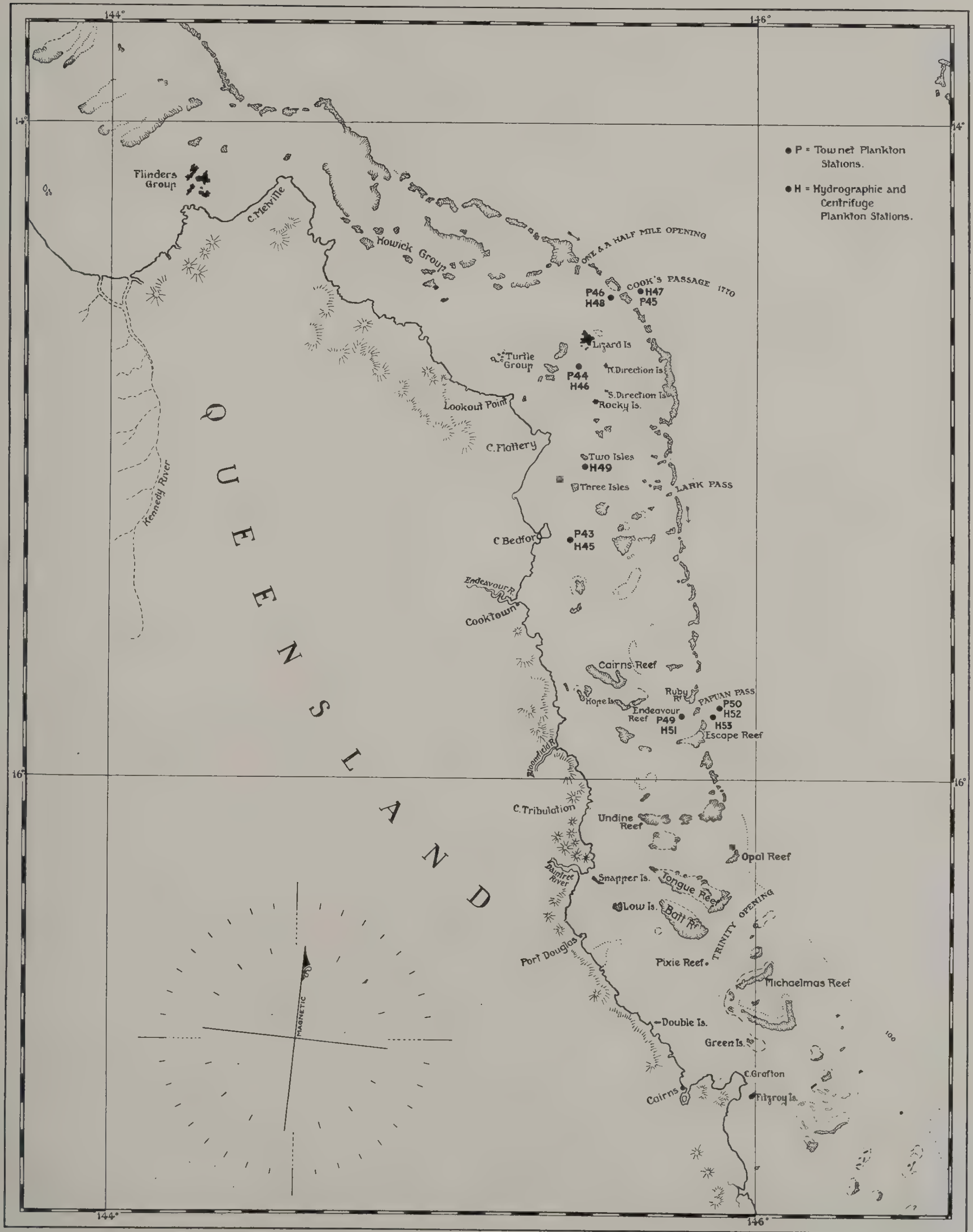
In the two charts (Plates I and II) reproduced, the hydrographic and plankton stations are marked to show the positions at which observations were made. The full details of the work are given in the papers on the hydrography, and phyto- and zoo-plankton which follow.

DESCRIPTION OF PLATE I.

Sketch chart of the Great Barrier Reef from Flinders to C. Grafton, indicating positions at which Hydrographic and Plankton Stations were made to the northward of Low Isles.

GREAT BARRIER REEF EXPEDITION 1928–29.

Brit. Mus. (Nat. Hist.). REPORTS, VOL. II, No. 1. PLATE I.


144°
146°
14°
16°
● P = Tow net Plankton Stations.
● H = Hydrographic and Centrifuge Plankton Stations.
Flinders Group
C. Melville
Howick Group
ONE & A HALF MILE OPENING
COOK'S PASSAGE 1770
P46
H48
H47
P45
Lizard Is
Turtle Group
P44
H46
N. Direction Is
S. Direction Is
Rocky Is.
Lookout Point
C. Flattery
Two Isles
H49
Three Isles
LARK PASS
Kennedy River
QUEENSLAND
C. Bedford
P43
H45
Endeavour R.
Cooktown
Cairns Reef
Ruby Rf
PAPUAN PASS
Hope Is
Endeavour Reef
P49
H51
P50
H52
H53
Escape Reef
Bloomfield R.
C. Tribulation
Undine Reef
Opal Reef
Daintree River
Snapper Is.
Tongue Reef
Low Is.
Batt Rf
TRINITY OPENING
Port Douglas
Pixie Reef
Michaelmas Reef
MAGNETIC
Double Is.
Green Is.
100
C. Grafton
Cairns
Fitzroy Is.

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DESCRIPTION OF PLATE II.

Chart of the region around Low Isles, indicating the positions at which Hydrographic and Plankton Stations were made.

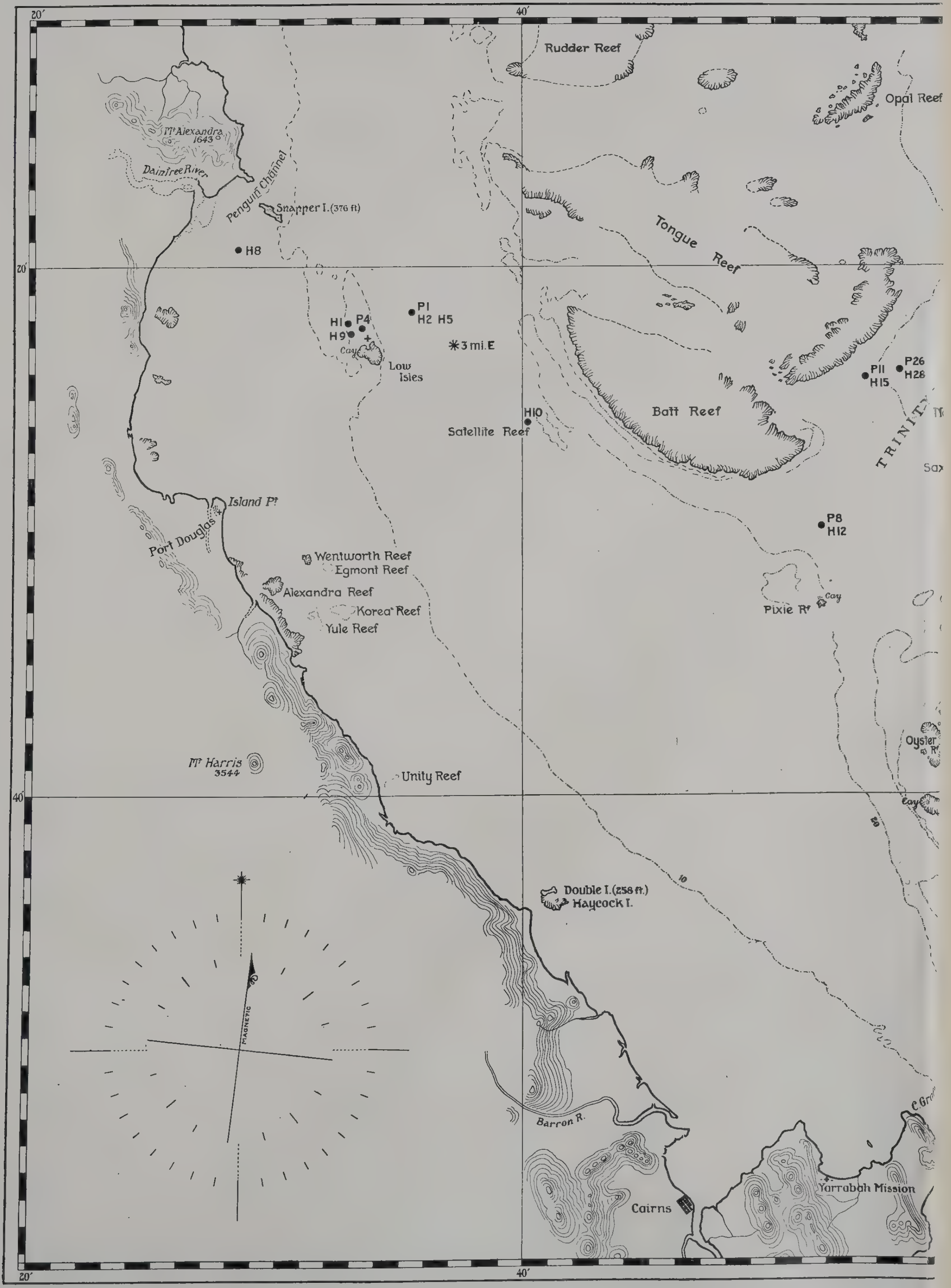
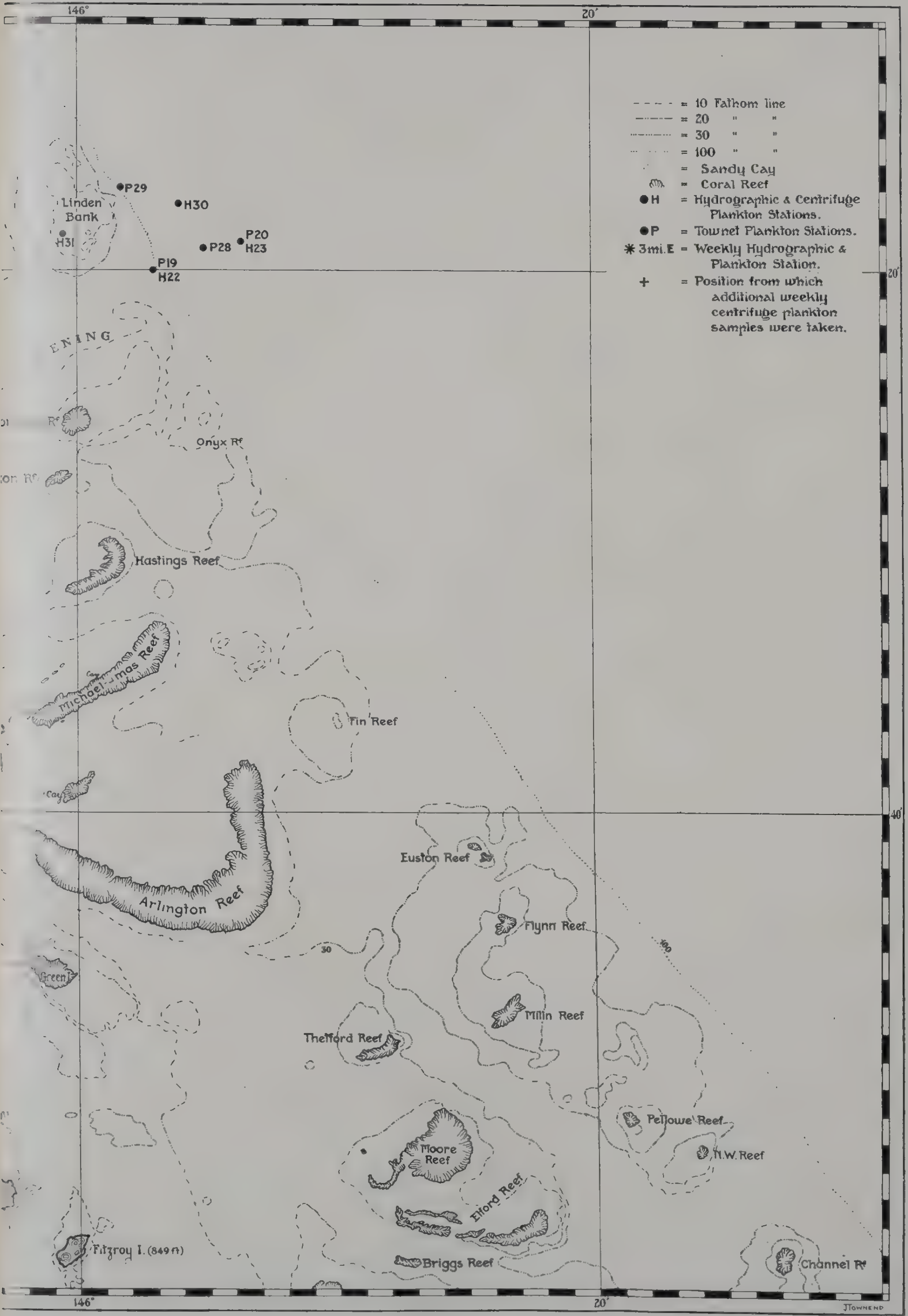

20′
40′
Rudder Reef
Opal Reef
Mt Alexandra
1643
Daintree River
Penguin Channel
Snapper I. (376 ft)
H8
Tongue Reef
P1
H2 H5
H1
P4
H9
Cay
Low Isles
3 mi. E
Batt Reef
H10
Satellite Reef
P11
H15
P26
H28
TRINIT
Sax
P8
H12
Island Pt
Port Douglas
Wentworth Reef
Egmont Reef
Alexandra Reef
Korea Reef
Yule Reef
Pixie Rf
Cay
Oyster Rf
Mt Harris
3544
Unity Reef
Cay
20
10
Double I. (258 ft.)
Haycock I.
MAGNETIC
Barron R.
Cairns
Yarrabah Mission
C. Gra

PLATE II.


146°
20'
---- = 10 Fathom line
= 20 " "
= 30 " "
= 100 " "
= Sandy Cay
= Coral Reef
●H = Hydrographic & Centrifuge Plankton Stations.
●P = Townet Plankton Stations.
✱ 3mi.E = Weekly Hydrographic & Plankton Station.
+ = Position from which additional weekly centrifuge plankton samples were taken.
P29
H30
Linden Bank
H31
P28
P20
H23
P19
H22
20'
ENING
Rf
Onyx Rf
on Rf
Hastings Reef
Michael-mas Reef
Fin Reef
Cay
40'
Euston Reef
Arlington Reef
Flynn Reef
30
100
Green
Milln Reef
Thetford Reef
Pellowe Reef
Moore Reef
N.W. Reef
Elford Reef
Fitzroy I. (849 ft)
Briggs Reef
Channel Rf
146°
20'
J.TOWNEND

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DESCRIPTION OF PLATE III.

FIG. 1.—The "Luana."

FIG. 2.—Collecting water samples in Trinity Opening on board the "Luana."

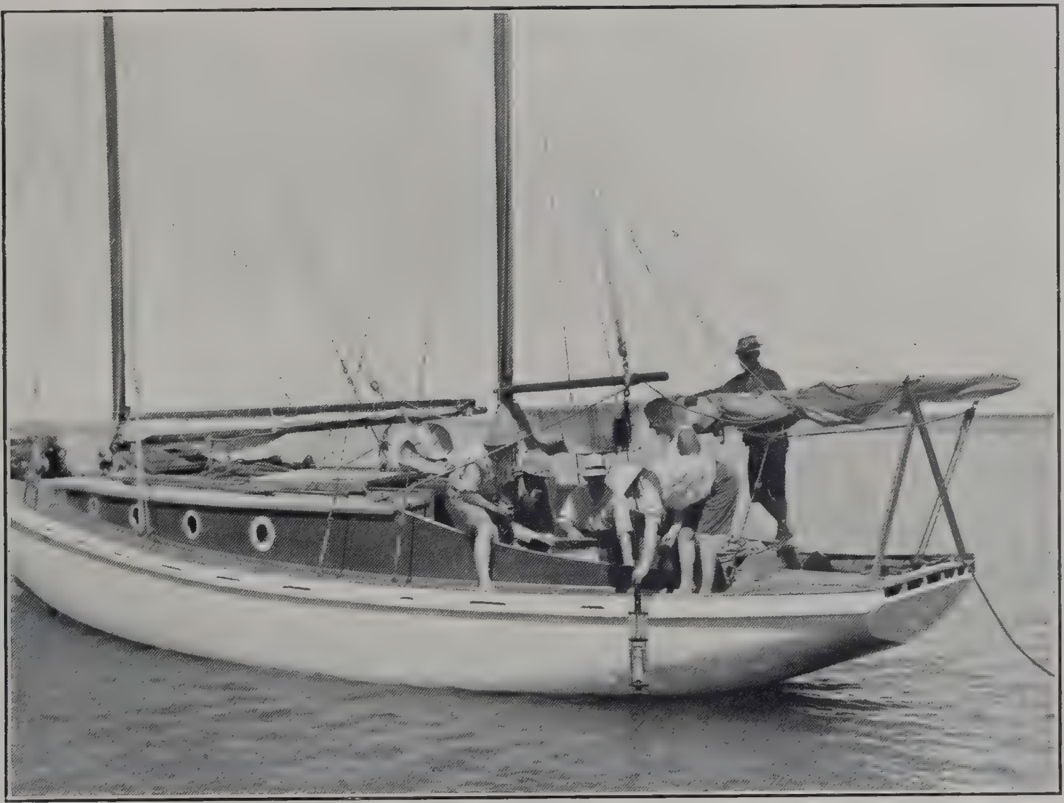

Photo C. Barrett.]

FIG. 1.

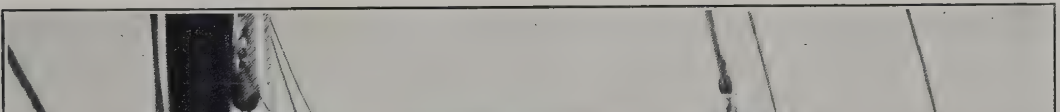

Photo F. S. Russell.]

FIG. 2.

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INVESTIGATIONS

THE ZOOPLANKTON

I. GEAR, METHODS AND STATION LISTS

BY

F. S. RUSSELL, D.S.C., B.A., AND J. S. COLMAN, B.A.

WITH NINE FIGURES IN THE TEXT AND ONE PLATE

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REFERENCES 27
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As pointed out in the introductory report on the work of the boat party (p. 3), the study of plankton on the western side of the Pacific has received little attention, except in the region of the Philippines and Dutch East Indies; and even in this latter area the collections have only been made on the cruises of expeditions and have not been spread over any period of time. No work of a quantitative character has been done, and there has been no published work on the plankton of the Great Barrier Reef region.

The objects of our plankton research were therefore twofold: firstly to study the abundance of the plankton animals throughout a whole year in one locality, and secondly, to obtain as complete a collection as possible of plankton organisms of all sizes to form an adequate basis of our knowledge of the species to be found in the region in which we were working. It was necessary, therefore, to fish with nets of different meshes, and to obtain quantitative data as to the abundance and importance of animals of different sizes. By carefully made collections it was hoped that not only would it be possible to arrive at the seasonal changes in abundance of the different organisms that comprise the plankton, but that also comparative data would be obtained from which some idea could be gained of the richness of the plankton as food for other organisms as compared with data from other parts of the world.

To this end, not only were oblique hauls (see p. 8) employed to ensure large enough catches to give significant results, but vertical hauls through a water column of known depth were also made to give information directly comparable with data obtained elsewhere.

This preliminary report gives a detailed account of the gear employed, the methods of oblique hauling, and the treatment of the collections.

In the introductory account of the work of the boat party a short description of the region worked has already been given. At the station three miles east of Low Isles, which was chosen for the weekly observations, collections were made with the one-metre stramin net and the coarse and fine international silk tow-nets, oblique hauls being made; at the same time a vertical haul from near the bottom to the surface was made with the coarse international silk tow-net. Similar collections were made in Trinity Opening and at other stations in the lagoon channel; but when working in deep water outside the barrier vertical hauls only, with stramin and silk nets, were made.

At the same time, owing to possible differences in the levels at which the various constituent species of the plankton live in the daytime, it was necessary to make some observations on their vertical distribution. Three stations were accordingly worked by day at the position three miles east of Low Isles, with the coarse international silk tow-net used as a closing net towed horizontally at different depths. Once a similar station was worked at night, and on another occasion oblique hauls with stramin and silk nets were taken, also at night, in order to find out which species, if any, lived close to the bottom, and only appeared in numbers on the upper layers after dark. These observations were supplemented by one haul with a stramin net, fishing actually on the bottom in the daytime.

Once a week, also, collections were made with a small silk tow-net from a rowing boat at high water in the shallow water over the reef flat of the island itself. These hauls were taken to obtain data on the abundance of plankton present in the actual vicinity of the living coral.

At the end of this report a full list of the plankton stations is given with all requisite data. For the details of the temperature and salinity observations, we are indebted to Mr. A. P. Orr, the data for the 10-metre level being taken as approximately representative of the general conditions, there being usually only slight variation from surface to bottom in the lagoon channel. Our thanks are due also to Mr. A. G. Nicholls for the observations given as to strength and direction of the wind on the dates on which our collections were made.

We should like here to express our gratitude to Mr. A. C. Wishart and Mr. H. C. Vidgen, for their invaluable assistance and patience in controlling the sailing speed of the vessel while collections were being made, and to Mrs. Russell, for much help given in recording the catches.

GEAR.

For regular sea work the expedition had at its disposal a ketch-rigged motor-yacht, fitted with a 26–30 h.p. sleeve-valve Kelvin engine; her length was 39 ft. and draught 3 ft. While designed primarily as a yacht for the tropics, with a large cabin space, the vessel nevertherless proved fully capable of the regular routine plankton collections in the inshore waters, although her deck space was necessarily somewhat cramped.

For the collection of plankton material the following nets were used:*

ONE-METRE STRAMIN NET.—Mouth 1 metre in diameter, with ring made of galvanized iron of ½ inch (12·7 mm.) diameter; weight, 3·1 kilos. The net itself was made of the hempen material known as stramin* (*ca.* 16 strands to the inch, or 7 to 1 cm.) and was 3 metres in length, tapering to a canvas band at its end, to take an enamelled tin bucket 22 cm. deep and 10·5 cm. in diameter; weight of bucket ·45 kilo.

---

* All plankton nets were made by the Marine Biological Association of the United Kingdom, Plymouth.

Coarse International Silk Tow-net.—Mouth 50 cm. in diameter, with ring made of galvanized iron $\frac{5}{8}$ in. (15·9 mm.) diameter; weight 1·7 kilos. The net itself was made of bolting silk of 58 strands to the inch,† or 23 to 1 cm., and was 2 metres in length, tapering to a canvas band to take an enamelled tin bucket 13 cm. deep and 8 cm. in diameter; weight of bucket ·23 kilo.

The dimensions of this net are the same as for that described by Ostenfeld and Jesperson (1924), for international investigations. It differed, however, in that the *silk was fastened direct to the iron ring* by means of a canvas band, *without* the $\frac{1}{2}$-in. meshed net that is usually inserted between the silk and the ring (see Plate I, fig. 1). It is thus known that the fishing capacity of the net was always the same from the point of view of the area of its mouth. Under strain the $\frac{1}{2}$-in. meshed netting tends to draw so that the virtual opening of the net, *i. e.* where the silk begins, may become more or less constricted, and is by no means equivalent to the constant opening of the iron ring. Experiments carried out by Künne (1929) have shown that a net with the $\frac{1}{2}$-in. meshing has a very much smaller fishing efficiency than one without, and it would seem desirable either that this netting be entirely dispensed with, as on this expedition, or that a wooden hoop be inserted between the netting and the silk to keep the opening of the silk portion of the net constant.

Fine International Silk Tow-net.—The dimensions and pattern of this net were exactly the same as those for the International Coarse Silk Net, but the bolting silk used was of 200 strands to the inch,‡ or 77 strands to 1 cm. The above three types of nets were fitted with eyelet holes in front so that they could be easily attached to or detached from the iron rings.

There were also used on occasion a Bottom Plankton Net of Stramin, which could be fished inside the Agassiz Trawl on the bottom as described by Russell (1928), and a 1-metre silk net 40 strands to the inch and 3 metres long for vertical hauls in deep water.

The *wire* on which the nets were worked was $\frac{3}{4}$ in. (19·1 mm.) circumference best extra flexible steel (6 strands, each of 24 wires, with hempen heart and hempen centre in each strand), approximate weight ·488 lb. per fathom or ·121 kilos per metre; it was stored on a small hand winch of simple design (Plate I, fig. 3), capable of taking about 400 metres of wire. With wire of this weight work with over 200 metres out becomes extremely heavy and a power winch should be employed. For work in shallow inshore waters it was extremely pleasant to handle, although admittedly it was unnecessarily strong for the plankton collecting; its great strength, however, enabled it to serve the dual purpose of plankton work in shallow waters, and of dredging in the deep waters beyond the barrier when it was transferred to a small friction winch, worked by a belt from a 2 h.p. motor.

The wire was run over a recording metre-wheel 50 cm. in circumference, of the pattern§ described by Knudsen (1923, p. 14).

---

* Stramin is sold in lengths 1 metre wide and can be obtained from Messrs. N. P. Utzon, Netmakers, Copenhagen, Denmark.

† This is XXXX No. 58 of Messrs. John Staniar & Co., Manchester Wire Works, Manchester, and No. 3 of Albert Wydler, of Zurich.

‡ This is X No. 25 of Messrs. John Staniar & Co., Manchester Wire Works, Manchester, and No. 25 of Albert Wydler, of Zurich.

§ Made at Den Polyteckniske Laereanstalt, Copenhagen, Denmark.

For work on vertical distribution of plankton, the releasing apparatus for closing horizontally towed nets described by one of us (Russell, 1925*a*) was used, with the slight modification that the two halves were hinged, instead of bolted, along one side.

METHODS OF COLLECTING.

For routine observations on the abundance of plankton, whether seasonal or geographical, it is essential that collections be made in as uniform a manner as possible, so that the results from different catches may be comparable. This end has been largely achieved for observations on the microscopic zoo-plankton and the phyto-plankton by centrifuging known volumes of water from samples collected in water-bottles from known depths. But for the small plankton animals, the most reliable method until recently has been by means of tow-nets hauled vertically. By this method the net can be hauled from an approximately known depth and the speed of hauling can be regulated.

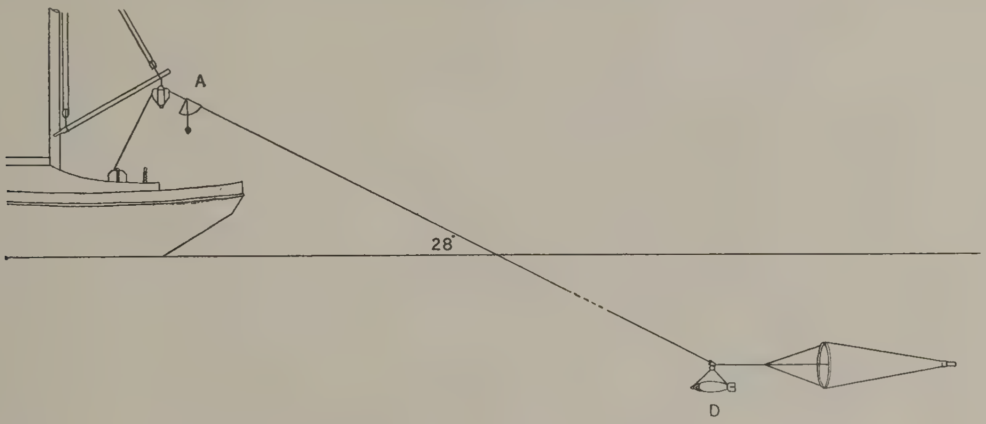
But in the vertical haul, the tow-net filters an insufficient volume of water to catch the larger plankton animals in great enough numbers to give reliable or significant results. There is an added disadvantage, which holds also for the smaller animals, that when the horizontal distribution of the plankton is uneven, due to small swarm formations, the vertically hauled net may only have sufficient time in the water to hit or miss a single swarm; a net towed horizontally for a longer time would hit and miss many swarms and so give a truer picture of the abundance of plankton present.

It is, therefore, advisable to use some method whereby the net shall be towed horizontally for a considerable time and, during this time, sample the water at all depths in order to overcome errors that might be produced by the uneven vertical distribution of the plankton. To this end, oblique or step hauls were made while studying the seasonal distribution of the zoo-plankton in the vicinity of Low Islands. The net was allowed to fish for equal lengths of time at successive and little separated depths from the surface downwards. Great care was taken that the speed of towing should be as near as possible the same from day to day. It was possible to obtain the required speed of the boat as a result of observations made on the angle at which the towing warp entered the water.

The warp ($\frac{3}{4}$-in. circumference flexible steel wire) was run off a hand-winch, bolted to a seat in the cockpit (Plate I, fig. 3) over a recording metre-wheel slung to a boom rigged outboard. The angle at which the warp entered the water was measured by a declinometer or angle-meter hung on the wire itself between the metre-wheel and the surface of the water (Text-fig. 1). In conjunction with this angle-metre, a depth-recording instrument was used which recorded the path of the net through the water. With the records so obtained it was possible to find the depth of the net with a given length of wire entering the water at a known angle. The instrument used was the Admiralty pattern depth-recorder previously used in research at Plymouth (Russell, 1925*b*), and as used by the "Discovery" Expedition (Kemp and Hardy, 1929, p. 197), and was kindly lent to the expedition by the Marine Biological Association; its weight in water was approximately $8\frac{1}{2}$ lb.

It was found by experience that the most comfortable speed for towing with the boat at our disposal was such that the towing warp entered the water at angles lying around 28°. In all collecting, therefore, every effort was made to keep the angle of entry as near as possible to 28°. Thus it could be presumed that the speed of towing was as near the same as practicable from day to day, and hence that the catches would be reasonably comparable.

It was soon found that it was not feasible to use the engine as motive power for towing the nets. The motor, designed for yachting purposes, could not be run at so slow a speed as that necessary. A fairly steady and sufficiently slow speed could, however, be maintained by use of the foresail and by judicious manipulation of the helm. Thus, for instance, while towing at the correct speed, which gave an angle of 28°, the breeze might freshen slightly so that the speed increased and the angle decreased to about 25° ; immediately, by bringing the vessel's head up gradually into the wind, her speed could be reduced until the required angle was reached once more. Conversely, with a slight slackening of the breeze the vessel's speed would be reduced ; the net would sink deeper in the water, and the angle of entry of the warp would rise to 30° ; this would at once be remedied by allowing the vessel's head to fall off, so increasing her speed.



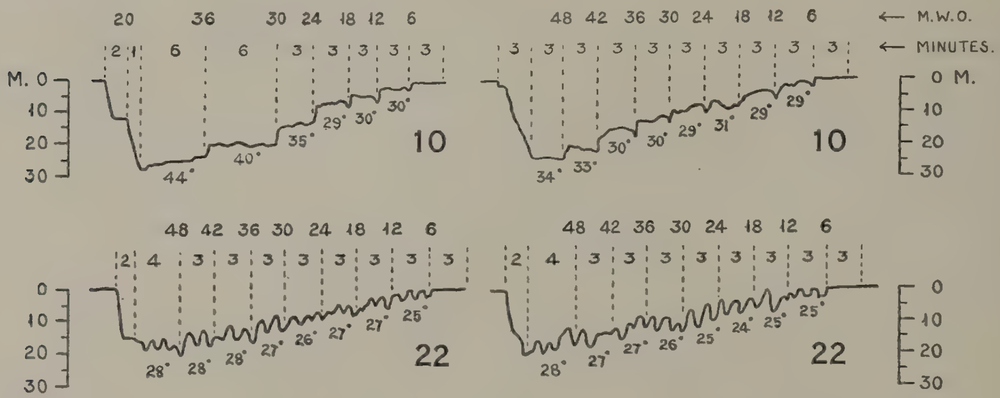
Text-fig. 1.—Diagram to show the fishing method adopted in making the oblique hauls. From the angle-metre, A, is read the angle at which the wire enters the water, the angle aimed at being 28°. Attached just in front of the net is the depth-recording instrument, D. The towing warp passes from a winch in the cockpit over a metre-wheel slung from the boom.

Each oblique haul was of 30 minutes' duration. The net was first towed for 3 minutes at the surface ; at the end of 3 minutes, 6 metres of wire were allowed to run off the winch, and the net fished thus for another 3 minutes, after which time a further 6 metres of wire were run out. Fishing was carried on in this manner with the net towing for periods of 3 minutes at successive depths by running off 6 metres of wire at a time until finally 48 metres were out. The net was towed then for 3½ to 4 minutes, after which time 2½ to 2 minutes were spent in hauling the net to the surface. In this way the total oblique haul was exactly 30 minutes long, and the net had fished during this time at nine successive depths, including the surface. All timing was done with a stop-watch.

While making the collections the 1-metre stramin net was used alone without a sinker, the weight of the depth-recording instrument itself acting in this capacity. The depth-recorder was shackled on at the junction between the towing warp and the bridles of the net (Text-fig. 1).

The coarse and fine silk tow-nets were used together, the depth-recorder being shackled at the junction of the warp and bridles of the coarse tow-net ; the fine tow-net was tied on to the warp about 2 metres above the coarse net. With these nets, also, there was no sinker used. Later, when the depth-recorder was no longer in use, a lead sinker of equivalent weight (8½ lbs.) was substituted.

The complete records obtained with the depth-recorder for the first 24 stations are reproduced in Text-figs. 2, 3, 4 and 5. In these figures are given tracings of the actual path of the net through the water on each occasion. The net enters the water on the right-hand side of each curve and leaves it on the left. The top row of figures above each curve gives the length of wire out in metres, and below it are given the intervals of time in minutes. Immediately beneath each curve are given the average angles of entry of the warp into the water for each successive amount of wire used; these are the averages of a number of angle readings taken during each 3-minute period. After Station 7 the angles were read at 20- to 30-second intervals throughout the period of collecting.

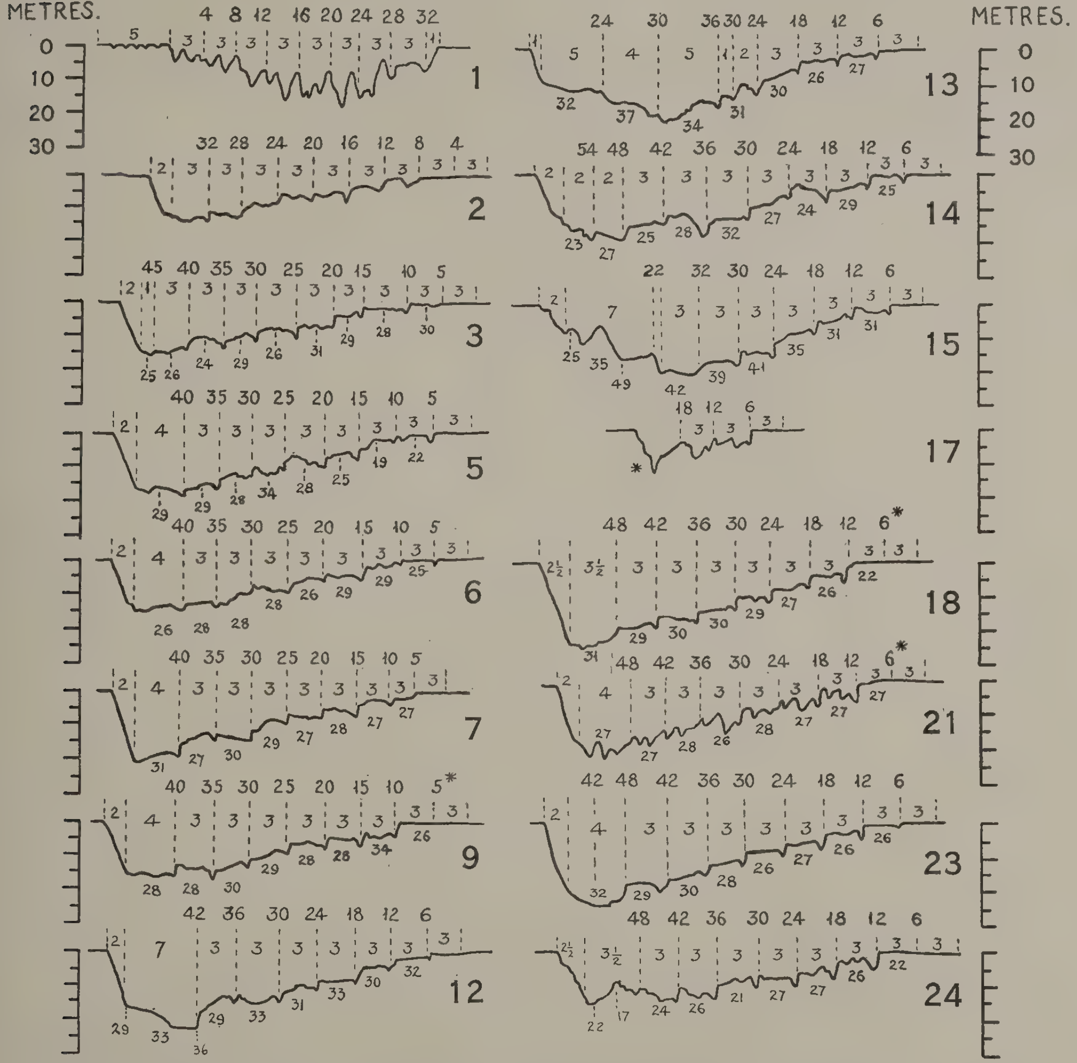


Text-fig. 2.—Examples of the graphic records of the path of the nets through the water obtained by the depth-recording instrument. These are for the oblique hauls at Stations 10 and 22, those on the left being with the fine and coarse international silk nets, and those on the right with the 1-metre stramin net. The nets enter the water on the right-hand side of the curves, and at succeeding intervals of usually 3 minutes additional lengths of 6 metres of towing wire are allowed out. The nets leave the water on the left-hand side. Below each 3-minute period is given the average angle of entry of the towing warp into the water for that period. The top curves illustrate the steady speed that could be obtained with the vessel towing under foresail, while those below show the effect produced on a calm day when the necessary speed was obtained by short kicks with the engine (see text, below). The depths are in metres.

It can be seen from these records that usually the angle of entry of the warp lay somewhere between 25° and 30°.

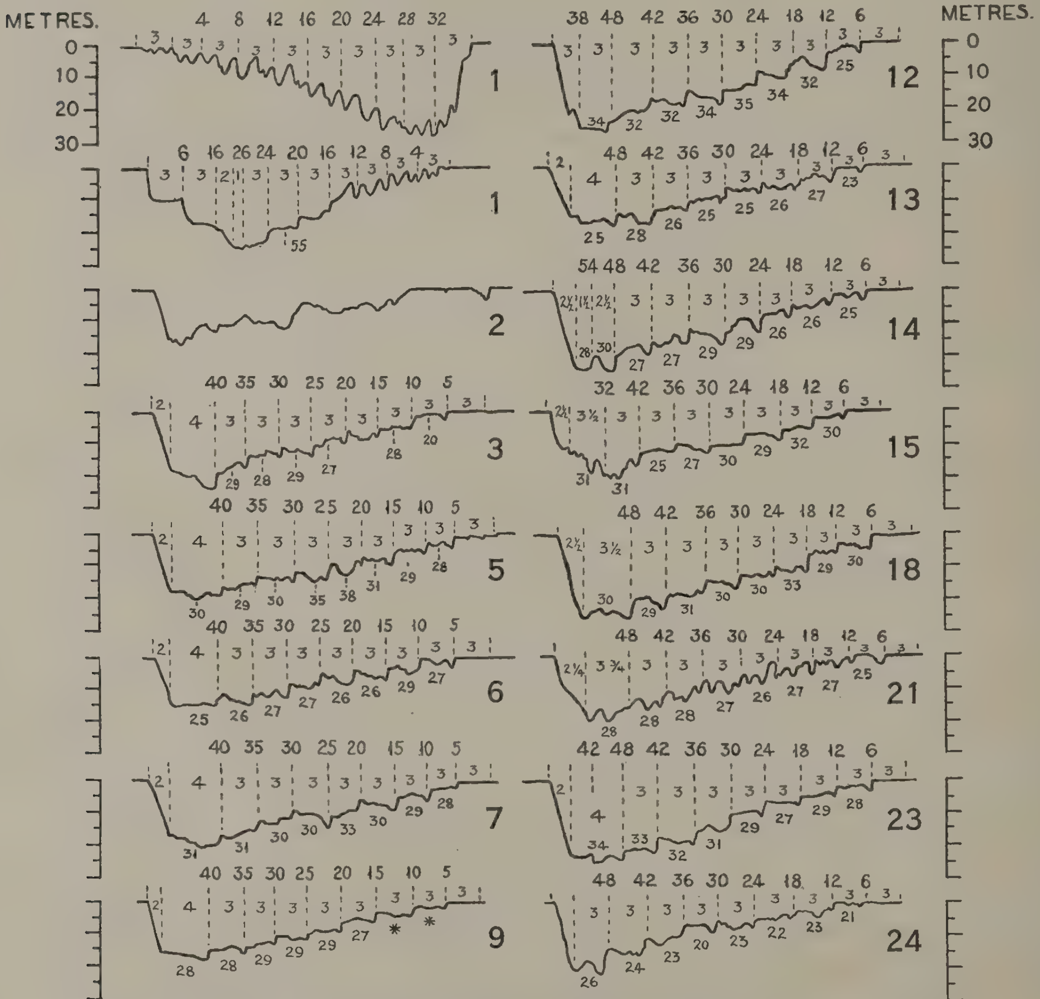
On occasion, when there was no breeze, it became necessary to use the engine. It has already been remarked that the engine could not be run at a sufficiently slow speed, and therefore, when used, towing speed had to be maintained by occasional short bursts. The motor would be run until an angle of 25° was recorded; it would then be stopped (or the clutch thrown out) until the speed fell off and the angle rose to 30°, when it would be started again and the speed increased until 25° was again recorded; and so on. In this manner, the angle was kept continually changing between 25° and 30°, giving an average between 27° and 28°.

In Text-fig. 2 are given examples of records from the depth-recorder, the two top curves being obtained with the fore-sail as motive power, and the lower two with the engine in use. The steady speed obtained with the fore-sail is in marked contrast to the jerky speed caused by using the engine on and off, which resulted in the alternate rising and sinking of the net in the water (see also Text-figs. 3 and 4, Stations 1 and 21). The upper tracings in Text-fig. 2 have been chosen to illustrate how sometimes with the vagaries of nature the wind would die away before a haul was completed. For instance, at Station 10, with the coarse and fine silk nets, the angles towards the end of the haul rose to over 40°. With the information available from previous records we were enabled to know that the



Text-fig. 3.—Depth records obtained during the oblique hauls with the 1-metre stramin net at the weekly stations 3 miles east of Low Isles. The large figures refer to the Station numbers. For description see Text-fig. 2. (* At Stations 9, 18 and 21 the piston of the depth record was probably stuck when the first interval of wire was paid out; at Station 17 the wire started to slip on the drum of the winch.)

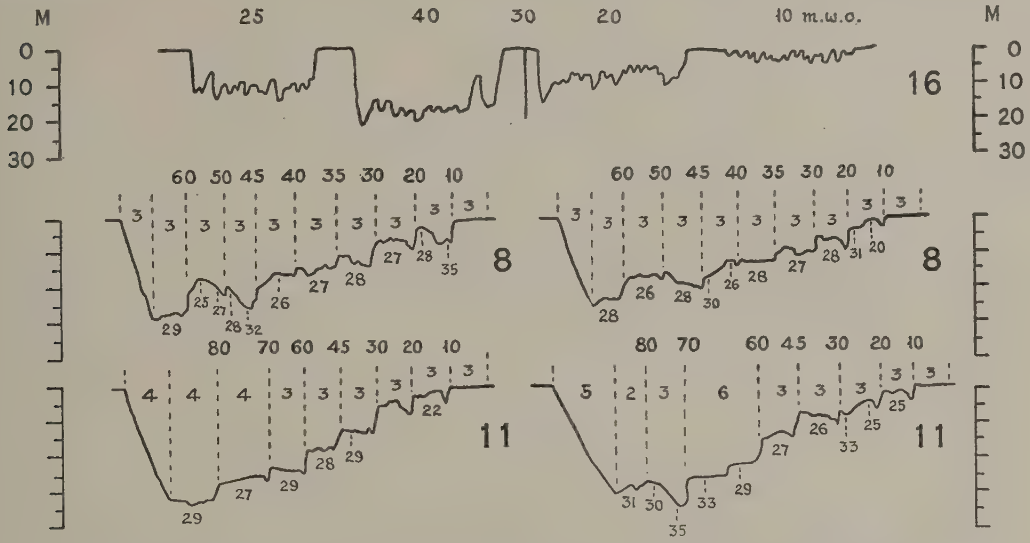
nets were sinking dangerously deep, and with the full length of 48 metres of wire would certainly strike the bottom at these slow speeds. The intervals at 30 and 36 metres of wire out were therefore lengthened on this occasion to 6 minutes ; at the end of the second six-minute period the net was sinking even deeper and it was deemed advisable to haul up ;



Text-fig. 4.—Depth records obtained during the oblique hauls with the fine and coarse silk international tow-nets at the weekly stations 3 miles east of Low Isles. The large figures refer to the Station numbers. For full description see Text-fig. 2.

accordingly 16 metres of wire were wound in and the net allowed to fish thus for a further short period to complete the 30-minute haul. It will be seen that similar tactics were adopted at Stations 13, 14 and 15 (Text-figs. 3 and 4).

With the help of these records it became possible to compile tables showing the depth at which the nets fished with a known amount of wire out entering the water at a given angle. Tables I and II give the results of a large number of angle-readings. Generally at least six angle-readings were taken during each three-minute period, so that it became possible to read off the depths for each angle-reading from the records. In the records reproduced in Text-figs. 2, 3, 4 and 5 only the average angles for each period are given; occasionally, *e. g.* Stations 12 and 24 (Text-fig. 3), the angles at any one moment are shown when the variations were very great. Space would not allow, however, of the publication of all the angle readings, and these are therefore condensed in summary form in Tables I and II. It can be seen from these tables that, allowing for occasional errors in reading the angle in rough weather, the depths fished for each length of wire out were remarkably constant.



TEXT-FIG. 5.—Depth records obtained at the vertical distribution Station 16 (clockwork drum was not revolving during the haul with 30 metres of wire out), and at Stations 8 and 11 in Trinity Opening. Those on the left are for the fine and coarse international silk tow-nets and those on the right for the 1-metre stramin net. For full description see Text-fig. 2.

Tables I and II also give the average depths of the nets for known lengths of wire out at given angles, and these averages have been plotted for 25°–26°, 27°–28°, and 29°–30° in Text-fig. 6. With these data we were enabled to predict the depth of the net at any moment to within about 2 metres, and after Station 24, when Mr. Russell returned to England with the depth recorder, it was possible to carry on routine collections in exactly the same way with a clear knowledge of how the net was fishing, and at the same time to be able to avoid any chance of the net going too deep and striking the bottom.

Examination of Text-fig. 6 shows that, as the lengths of wire are increased, the coarse and fine silk nets tend to fish slightly deeper for the same angle than does the stramin net. This is probably to be explained by the slightly greater weight of the two silk nets as opposed to the stramin net. With the greater lengths of wire out, the curve assumed by the wire in the water would tend to flatten out more at its lower end with the lighter net. The resistance of the large stramin net in the water might also be slightly greater than that of the two silk nets, though this is doubtful, owing to the very fine meshes of the silk, in spite of the smaller opening of these nets.

Table I.—*Showing the Depths in Metres given by the Depth Recorder, with the Correspondin*

The Average Dept

Length of wire out: metres.	Angle of entry										
	17°	18°	19°	20°	21°	22°	23°	24°	25°–26°	27°–28°	29°–30°
5	..	..	..	½ (½)	..	..	..	½, 1 (1)	1, 1 (1)	2, 1 (1½)	1, 2 (1½)
6	½ (½)	½ (½)	..	½ (½)	..	½, ½, ½, (½)	½ (½)	½, ½, ½ (½)	1, 1, ½ ,1, 1½, ½, ½, ½, 1 (1)	1, 1½, 1½, 2, 1½, 2, 1, 1, 1 (1½)	2, 2½, 1½, 1½ (2)
10	..	..	..	..	1 (1)	..	2 (2)	..	2, 2, 3, 2 (2)	2, 2, 2½ (2)	3, 4, 3, 4 (3½)
12	..	..	..	..	..	..	2 (2)	3, 3½, 2½, 2 (3)	3, 3, 3, 4, 4, 2½, 3, 3½, 3 (3)	3½, 3½, 3½, 3½, 4½, 3½, 3½, 3 (3½)	4, 4, 4½, 4, 4, 4 (4)
15	..	..	..	..	..	..	..	..	..	4½, 5, 5, 5, 4½, 4 (4½)	4½, 5, 5, 7, 6, 5 (5½)
18	..	..	..	3 (3)	3½ (3½)	4 (4)	4½ (4½)	4, 6½ (5)	5½, 5, 5½, 6, 5½ (5½)	6, 7, 6½, 6½, 6½, 6 (6½)	7, 7½, 7½, 7, 8, 6½, 6½ (7)
20	..	..	..	..	..	..	..	..	5½, 6, 7, 7, 5½ (6)	8, 8, 7, 6, 6, 7, 6 (7)	7, 7, 9½, 10½, 7, 8 (8)
22	..	..	..	..	..	..	6 (6)	..	9, 6½ (8)	8 (8)	11, 8½ (10)
24	..	..	..	..	..	..	..	6½ (6½)	7½, 8, 8, 8½, 8, 8, 7½ (8)	7½, 8, 9, 10½, 10½, 8½, 9, 8 (9)	9, 10, 10½, 10½, 10, 10, 11, 10 (10)
25	..	..	..	..	..	..	..	..	7, 9 (8)	9½, 8, 10, 8½ (9)	11 (11)
30	..	..	..	7 (7)	..	..	8½, 8 (8)	8½, 9½ (9)	8½, 9, 9, 8 (8½)	11, 10, 11, 9, 10, 13½, 11, 11, 11½ (11)	10, 12, 13, 14, 14, 14, 13½, 13, 10, 12, 13, 12, 14, 12½, 13½, 14, 12, 12½, 12½ (12½)
32	..	..	..	..	..	..	..	..	..	..	..
35	..	..	..	..	..	..	..	11 (11)	12, 13 (12½)	12½, 13, 14, 15, 13, 14, 13½ (13½)	13½ (13½)
36	..	..	..	..	..	..	11 (11)	12, 11 (11½)	13, 12, 12, 12½ (12½)	13, 16, 15, 15, 13, 13½ (14)	16, 15, 13½, 15½, 15, 16, 16½, 16, 15½ (15½)
40	..	..	..	..	..	..	..	..	15, 14, 13, 14, 13 (14)	15, 15, 13, 14, 15½, 16 (15)	18, 19, 16, 17, 16½ (17½)
42	..	..	..	..	..	13 (13)	12, 11½ (12)	..	14, 13½, 15, 17½, 14, 14½, 14 (14½)	18 (18)	17, 16½, 19½, 18½, 18, 17½, 18 (18)
45	..	..	..	..	..	..	..	..	16, 17, 13 (15½)	19, 14, 15½ (16)	20, 19 (19½)
48	9 (9)	10½ (10½)	11 (11)	11½ 14 (13)	15½ (15½)	..	..	..	16½ (16½)	19 (19)	23, 24, 21 (22½)
50	..	..	..	..	..	..	..	..	17, 17 (17)	17 (17)	..
54	..	..	..	..	..	16 (16)	..	17½ (17½)	..	..	..
60	..	..	..	..	..	..	..	..	23 (23)	23, 22½ (23)	24, 25, 23 (24)
70	..	..	..	..	..	..	..	..	..	..	28½ (28½)
80	..	..	..	..	..	..	..	..	..	..	29 (29)

gles of Entry of the Wire and the Lengths of Wire Out. 1 *Metre Stramin Net.*

given in Brackets.

into water.

31°	32°	33°	34°	35°	36°	37°	38°	39°	40°	41°	42°	43°	46°	49°	50°
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2, 2 (2)	2, 2 (2)	2½, 2 (2)	2½, 2 2 (2)	..	2½ (2½)	..	..	..	..	..	..	..	..	..	..
4 (4)	3½, 3½ (3½)	..	4 (4)	4 (4)	..	5 (5)	..	..	..	..	..	..	..	..	..
5½, 5, 4½, 5 (5)	4½, 5 (5)	5 (5)	..	5½ (5½)	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7, 7 (7)	8½, 8, 8, 9 (8½)	9, 8, 8 (8½)	8½, 9, 9½, 8½ (9)	10 (10)	..	..	11 (11)	..	11½ (11½)	..	..	..	..	..	..
..	..	8½ (8½)	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	10 (10)	..	..	..	12 (12)	14 (14)	..	..	15½ (15½)	16 (16)	16 (16)	16½ (16½)
11, 11, 11 (11)	12, 11½, 12, 12 (12)	13, 12½ (13)	13 (13)	12½ (12½)	..	..	..	..	14, 14 (14)	..	14½ (14½)	..	..	..	..
12 (12)	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
13, 13, 13, 14½, 13½, 13½ (13½)	14, 14, 9 (12½)	15, 15½, 15 (15)	15,16, 16 (15½)	16½ (16½)	17½ (17½)	17 (17)	17 (17)	17, 17½ (17)	19, 17 18 (18)	..	20 (20)	..	..	..	..
..	..	..	..	..	..	..	..	19½ (19½)	..	19½ (19½)	21, 20 (20½)	21 (21)	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
17½, 18, 16 (17)	16½, 17½, 16½ (17)	..	19 (19)	19½ (19½)	..	21 (21)	22 (22)	..	..	..	..	..	..	..	..
..	..	..	21 (21)	21 (21)	..	..	..	..	..	..	..	..	..	..	..
17 (17)	21, 19½ (20)	..	22, 20 (21)	22 (22)	23, 22½ (23)	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
22 (22)	23½, 24½, 23, 23 (23½)	24, 24, 24 (24)	24,25, 24½ (24½)	24½ (24½)	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
23 (23)	..	24, 26 (25)	26 (26)	26½ (26½)	27 (27)	..	..	..	..	..	..	..	..	..	..
28 (28)	30½ (30½)	..	..	33 (33)	..	..	..	..	..	..	..	..	..	..	..
30½ (30½)	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

From the depth records it has been possible to measure the maximum depths fished by the nets on each occasion, and these are given below :

Station number.	Maximum depth in metres.	
	1 m. stramin net.	Fine and coarse silk nets.
1	17·5	28 (bottom) 24·5
2	14	17
3	15	23·5
5	19	20
6	15	15
7	21	20·5
8	(25·5)	(28·5)
9	16·5	17
10	24·5	28
11	(34·5)	(33)
12	23	27·5
13	22	19
14	19	25
15	21	21
17	(12·5)	—
18	25	25·5
21	22	20·5
22	20	20·5
23	24	25·5
24	15·5	22·5
	(Average = **21·6**)*	(Average = **23·5**)*

N.B.—The figures in brackets were at Trinity Opening Stations, 8 and 11. At Station 17 the wire started slipping off the winch.

From these figures it can be seen that from Station 10 onwards, when the experience of the first few stations had shown that 48 metres of wire was a safe maximum, and excluding Station 11 in Trinity Opening and Station 17, which was not concluded, the average maximum depth was for the 1-metre stramin net 21·6 metres, and for the coarse and fine nets 23·5 metres. This average of about 10 metres above the bottom (32 m.) was necessary as a safety margin to allow for the sudden sinking of the net if the wind dropped; a similar margin has also been found necessary with a 2-metre ring-trawl worked from a steam vessel (Russell, 1926, p. 390). Taking the above average depths, 21·6 and 23·5 metres, the distances between the successive levels at which the nets fished during an oblique haul of 30 minutes with three-minute intervals would be for the stramin net 2·7 metres, and for the coarse and fine silk nets 2·9 metres. When the diameters of the nets are taken into consideration these distances are reduced to 1·7 and 2·4 metres respectively; and these latter intervals would easily be covered by the rising and sinking of the nets due to variations in towing speed. It can therefore be said that *all* layers from the surface down to 21·6 and 23·5 metres, as the case may be, were thoroughly sampled as though by a vertical haul through the same distance, but very much more efficiently on account of the longer time of the oblique haul.

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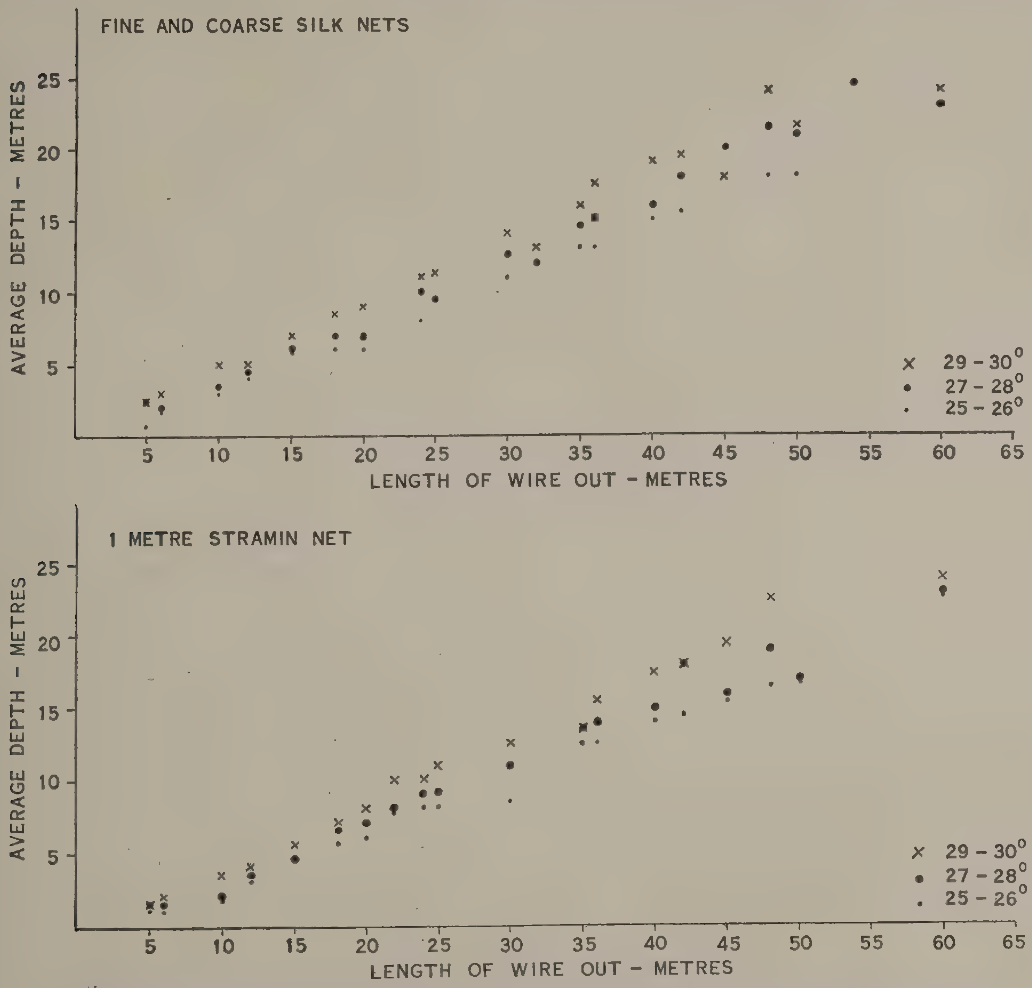
* The average is taken from Station 10 onwards, excluding Stations 11 and 17.

But at this stage a somewhat serious criticism can be raised against the use of oblique hauls in shallow waters where there is risk of striking bottom. The depth at the position at which our regular weekly collections were made was 32 metres, and the vertical haul was made from 28 metres. Therefore on an average there remained about 5 metres of the deeper layers unsampled by the oblique haul which would have been passed through in a vertical haul. It can seriously be argued that differences in vertical distribution of the plankton animals from day to day may give rise to large errors when oblique hauls only are used. On bright days, or when the water is very clear, it may well be that a large proportion of the plankton animals are congregated in the lower 10 metres ; these would not be caught by the oblique haul, but a great many of them would be taken in a vertical haul. Conversely, if the day be dull, or the water very opaque, the animals might mostly



Text-fig. 6.—The average depths at which the nets fished, as shown by the depth recorder, plotted against the length of wire out at the given angles of entry of the warp into the water.

TABLE II.—*Showing the Depths in Metres given by the Depth Recorder, with the Corresponding Angle*

The Average Depth

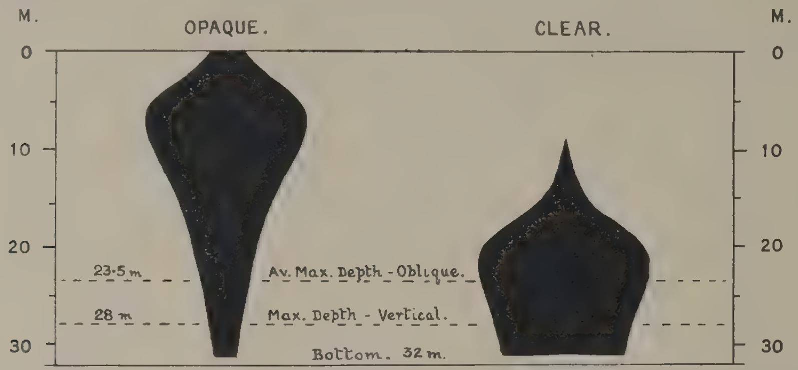
Length of wire out—metres.	Angle of entry									
	18°	19°	20°	21°	22°	23°	24°	25°–26°	27°–28°	29°–30°
5	..	..	½ (½)	..	..	..	..	1, ½, ½ (⅔)	2, 2, 2½, 3 (2½)	2½ (2½)
6	..	..	½, ½ (½)	1, 1 (1)	1½, 1, 1, 1½, 1½ (1½)	1 (1)	2, 1, 2, 2 (2)	2½, 1½, 2, 1½, 3 (2)	3, 2½, 2, 1½, 2, 2 (2)	2½, 2½, 3½, 3½, 3, 2½ (3)
10	..	..	2 (2)	..	2½, 3 (3)	..	3 (3)	3 (3)	4, 3½, 3½, 3½, 2½ (3½)	5, 5, 4 (5)
12	..	..	..	2½ (2½)	3, 3 (3)	3, 3 (3)	..	3, 4, 5, 3½ (4)	4½, 4½, 3½, 4, 5½, 5, 5, 4, 4, 4½ (4½)	5, 5, 5½, 5, 5, 5½, 5½, 5½, 5 (5)
15	..	..	..	..	..	4 (4)	..	7, 5 (6)	6, 5½ (6)	7½, 7 (7)
18	..	..	..	4 (4)	4½ (4½)	5 (5)	6, 5½ (6)	6, 6, 5½, 6½, 7, 6½ (6)	6½, 7, 6½, 7, 6½, 7½, 7, 7½, 7, 6½, 7 (7)	7½, 9, 8, 10 (8½)
20	..	..	..	..	..	..	5½ (5½)	6½, 6, 6 (6)	8½, 8, 6, 6, 6½, 8 (7)	10, 9 (9½)
24	..	..	6½ (6½)	6 (6)	6½ (6½)	..	7, 7½, 9, 7, 7 (7½)	7½, 7, 9, 8 (8)	9½, 10, 10 (10)	12, 11, 12, 10½, 11, 11, 12, 12, 11 (11)
25	..	..	..	..	..	..	..	..	8, 10, 10½ (9½)	12, 11½, 10½, 11½, 12 (11½)
30	6½ (6½)	6½, 6½ (6½)	7 (7)	8 (8)	..	..	10, 10½ (10)	10½, 11, 10½, 12, 12, 11 (11)	13, 10, 13, 12½, 13, 12½, 13½, 13, 12½ (12½)	14, 12½, 12, 13½, 14, 13, 15, 14, 15, 14½, 14, 14, 14½ (14)
32	..	..	..	..	..	..	..	..	13, 11½, 12 (12)	13 (13)
35	..	..	..	..	..	..	..	11½, 14 (13)	13, 13½, 15, 16½, 15 (14½)	17, 16, 15½ (16)
36	..	..	..	..	11 (11)	11½ (11½)	12, 13 (12½)	13, 13, 14½, 14, 13, 12, 12½ (13)	13½, 13½, 16, 16, 16 (15)	17, 17, 18, 18 (17½)
40	..	..	..	..	..	..	..	14½ ,14½, 16 (15)	16, 16½, 16 (16)	21, 20, 19, 19, 18, 17 (19)
42	..	..	..	..	..	15, 14½ (15)	15½ (15½)	15, 16½, 15, 16 (15½)	17, 16, 18, 17, 20, 20, 19½ (18)	20½, 17½, 18, 20, 20½, 21, 20, 20, 20½ (19½)
45	..	..	..	..	..	..	..	..	23½, 21, 18, 18 (20)	18 (18)
48	..	..	..	..	..	18 (18)	17 (17)	16½, 16, 17½, 17, 21, 20 (18)	20, 23, 21½ (21½)	23, 24½, 24, 24½, 23, 25½ (24)
50	..	..	..	..	..	..	..	19, 17½ (18)	21 (21)	21½ (21½)
54	..	..	..	..	..	..	..	..	24½, 24½, 25 (24½)	..
60	..	..	..	..	..	..	..	..	22½, 22½, 23½ (23)	23½, 24, 24, 23½ (24)
70	..	..	..	..	..	..	..	26½ (26½)	25½, 25½, 27 (26)	..
80	..	..	..	..	..	..	..	..	33, 32 (32½)	33½, 34, 32 (33)

' Entry of the Wire and the Lengths of Wire Out. Fine and Coarse International Silk Tow-nets.

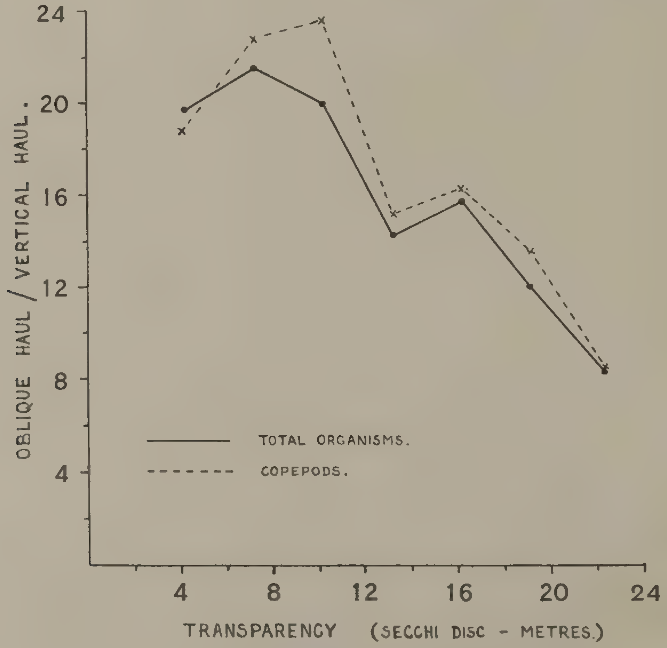
e given in Brackets.

re into water.														
31°	32°	33°	34°	35°	36°	37°	38°	40°	41°	42°	43°	45°	46°	49°
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3, 2½, 2½ (3)	2½ (2½)	4 (4)	..	3 (3)	..	..	..	..	..	..	..	..	..	..
..	6½ (6½)	4½ (4½)	..	7 (7)	..	..	..	..	..	..	..	..	..	..
6, 6½ (6)	8, 6 (7)	8½ (8½)	7, 6 (6½)	6½ (6½)	..	8 (8)	..	..	..	..	..	..	..	..
8 (8)	8 (8)	..	..	..	..	..	..	..	..	..	..	..	..	..
8½, 10½ (9½)	11, 11½ (11)	11 (11)	10 (10)	11½, 11½ (11½)	11, 12 (11½)	..	..	..	..	..	..	..	..	..
..	11 (11)	..	11½ (11½)	12 (12)	..	..	12½ (12½)	12½ (12½)	13 (13)	..	..	..	..	..
11, 12, 13, 12½ (12)	..	..	14, 13, 13½, 13 (13½)	15 (15)	14½, 14½ (14½)	15 (15)	..	..	..	..	..	..	..	..
..	13½ (13½)	13 (13)	..	14 (14)	..	..	..	..	..	..	..	..	..	..
16, 16, 15 (16)	15, 16½, 15½, 15½ (15½)	16, 16 (16)	17, 16½ (17)	..	19 (19)	..	..	20½, 20½, 20½, 20 (20½)	20½ (20½)	..	..	..	..	..
..	..	15 (15)	..	..	18 (18)	..	..	..	19 (19)	..	..	..	..	..
16½, 17 (17)	..	..	..	..	..	..	..	..	..	..	..	..	..	..
17½, 17, 18, 19, 18½, 19½, 18½, 18 (18)	19, 18½, 19, 19½ (19)	19, 20 (19½)	..	..	..	..	..	24 (24)	..	25, 25½ (25)	25½ (25½)	26½ (26½)	27½ (27½)	28 (28)
21, 20 (20½)	20½ (20½)	..	..	..	..	..	..	..	..	..	..	..	..	..
21, 21, 17, 22 (20½)	22½, 21½, 21½ (22)	21½, 21½, 22 (21½)	23½, 22, 22½ (22½)	24, 23, 24, 24 (24)	24 (24)	..	..	..	..	..	..	..	..	..
25 (25)	25½ (25½)	..	..	..	..	..	..	..	..	..	..	..	..	..
25, 25½, 23½ (24½)	25½, 24, 26 (25)	25 (25)	26, 26, 25½ (26)	26½, 25½ (26)	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

be above the lower 10 metres, when the oblique haul would catch almost as many animals per unit volume of water filtered as would the vertical haul (Text-fig. 7).



Text-fig. 7.—Diagram to illustrate how, on days with clear water, the plankton animals might be deep down so that far more would be caught in the vertical net as compared with the obliquely hauled net than would be the case if the water were opaque and the animals well above the bottom.



Text-fig. 8.—Graphs showing the factor $\frac{\text{oblique haul catches}}{\text{vertical haul catches}}$ plotted against the transparency of the water as shown by the Secchi disc. (See text, p. 21.)

That such may indeed be the case receives strong support from the results of our collections. On almost every day that the oblique hauls wére taken with the coarse silk tow-net, vertical hauls were also made with the same net. The net was hauled vertically from a depth of 28 metres, so that there were usually 5 or 6 metres sampled in the deeper

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layers through which the oblique haul did not fish. If the criticism outlined above holds, it would be expected that the factor for $\frac{\text{oblique haul catch}}{\text{vertical haul catch}}$ would be greater on those days when the animals were higher in the water than when they were deep down. Accordingly, this factor has been worked out for all days on which both vertical and oblique hauls were taken. The factors obtained are compared in the following Tables III and IV, against the transparency of the water on the days in question. The transparency of the water was measured by means of a Secchi disc, 20 cm. in diameter, and the variations in opacity were probably fully great enough to affect the vertical distribution of the plankton animals. In Table III the results are given for the total number of organisms in the catches, and in Table IV for the Copepods alone.

TABLE III.—*Total Organisms; the Factors* (F), $\frac{\textit{Oblique Haul Catch}}{\textit{Vertical Haul Catch}}$ *at the Stations Given.*

Depths in Metres at which Secchi Disc Disappeared.													
3–5½.		6–8½.		9–11½.		12–14½.		15–17½.		18–20½.		21 +.	
St.	F.	St.	F.	St.	F.	St.	F.	St.	F.	St.	F.	St.	F.
25	19·4	9	18·2	7	17·4	14	11·6	10	23·9	12	10·9	41	9·2
48	15·6	13	17·7	33	22·6	39	8·4	24	10·5	22	7·1	42	8·1
51	31·7	18	25·7	66	20·7	52	9·7	27	32·6	23	24·6	..	..
54	17·2	53	19·1	67	19·3	57	32·1	32	(72·2)	34	9·4	..	..
56	17·7	58	20·7	..	..	60	14·0	35	14·1	38	17·2	..	..
61	16·5	59	28·5	..	..	..	..	37	7·2	55	9·0	..	..
..	..	..	..	..	..	..	..	40	19·4	..	..	..	..
..	..	..	..	..	..	..	..	47	6·4	..	..	..	..
Average	**19·7**		**21·6**		**20·0**		**15·2**		**16·3**		**13·6**		**8·6**

TABLE IV.—*Total Copepods; the Factors* (F), $\frac{\textit{Oblique Haul Catch}}{\textit{Vertical Haul Catch}}$ *at the Stations Given.*

Depths in Metres at which Secchi Disc Disappeared.													
3–5½.		6–8½.		9–11½.		12–14½.		15–17½.		18–20½.		21 +.	
St.	F.	St.	F.	St	F.	St.	F.	St.	F.	St.	F.	St.	F.
25	21·2	9	17·2	7	17·8	14	19·7	10	22·9	12	11·5	41	9·1
48	15·5	13	18·1	33	34·5	39	7·6	24	8·8	22	16·6	42	7·8
51	30·8	18	32·7	66	23·1	52	9·6	27	23·8	23	12·9	..	..
54	16·7	53	20·1	67	18·9	57	21·7	32	20·7	34	10·6	..	..
56	14·4	58	22·9	...	..	60	12·3	35	18·2	38	14·7	..	..
61	14·6	59	26·2	..	..	..	..	37	4·3	55	6·4	..	..
..	..	..	..	..	..	..	..	40	21·4	..	..	..	..
..	..	..	..	..	..	..	..	47	6·0	..	..	..	..
Average	**18·9**		**22·9**		**23·6**		**14·2**		**15·8**		**12·1**		**8·4**

It can be seen from these tables that the *average* factors show a definite decrease as the transparency of the water increases. These average factors are plotted in Text-fig. 8, which shows the results in a striking manner. Inspections of the figures in Tables III and IV shows, however, that the variations of the factors in any one column are very great. This is to be expected on account of the unreliability of the vertical haul when organisms are unevenly distributed horizontally (see page 8). But, on averaging, these variations are smoothed out, and produce results that it is difficult to believe have no significance. That there must be some significance in the results is strengthened by the following Correlation Tables V and VI, which give the numbers of the occurrences of the different factors at the different degrees of transparency.

TABLE V.—*Total Organisms. Number of Times the Different-sized Factors Occurred at the Given Transparencies of the Water.*

	Transparency.						
	3–5½.	6–8½.	9–11½.	12–14½.	15–17½.	18–20½.	21 +.
Factor 30– . . .	1	..	..	1	2	..	..
,, 25–29·9 . .	..	2	..	..	..	..	..
,, 20–24·9 . .	..	1	2	..	1	1	..
,, 15–19·9 . .	5	3	2	..	1	1	..
,, 10–14·9 . .	..	..	..	2	2	1	..
,, 5–9·9 . .	..	..	..	2	2	3	2
,, 0–4·9 . .	..	..	..	..	..	..	..

TABLE VI.—*Copepods. Number of Times the Different-sized Factors Occurred at the Given Transparencies of the Water.*

	Transparency.						
	3–5½.	6–8½.	9–11½.	12–14½.	15–17½.	18–20½.	21 +.
Factor 30 + . .	1	1	1	..	..	..	..
,, 25–29·9 . .	..	1	..	..	..	..	..
,, 20–24·9 . .	1	2	1	1	4	..	..
,, 15–19·9 . .	2	2	2	1	1	1	..
,, 10–14·9 . .	2	..	..	1	..	4	..
,, 5–9·9 . .	..	..	..	2	2	1	2
,, 0–4·9 . .	..	..	..	..	1	..	..

If now from Table III we regard the average maximum factor of $\frac{\text{oblique haul catch}}{\text{vertical haul catch}}$ to be 21, it should be possible, taking this figure as a starting-point, to correct for errors that may have arisen in the observations on the seasonal abundance of the plankton, because of changes in the transparency of the water. Catches made on days when the Secchi disc reading was between 18 and 20 metres should, after correction, be 21/13 times as large. At any rate, before drawing conclusions about seasonal abundance of animals that are not surface-living, the transparency of the water must be taken into consideration.

The method of oblique hauling has been described here at some length, as it is necessary that some such method of collecting should be brought into general use, especially for the larger plankton animals. The oblique hauls described above can be carried out by anyone from a small vessel in shallow coastal waters, and the data given here as to depths at which the nets fish can be utilized, *provided* that care is taken to use the same type of gear in every respect. It is essential that the weights of the nets and hauling warp and sinker be the same as those used here, for it is on these, as well as on their frictional resistance through the water, that the depth of the net at a given angle depends. For this reason, in the section on p. 7 about nets and gear, full details are given as to their weights.

Recently the practice of oblique hauling has been followed by the "Discovery" Expedition (Kemp and Hardy, 1929, p. 202). The method used was the reverse of that described above, namely, the full amount of wire was paid out at the start, and then, while towing slowly at 2 knots, the net was hauled in at a speed of 10 metres a minute.

This method is practicable in deep waters, where the maximum depth to be fished is far above the bottom; but in shallow waters it is unsafe: either the net will sink too deeply before its correct fishing speed has been attained and strike the bottom, or it will have to be fished at first at far too great a speed, and never reach the required depth. The method employed was, therefore, to arrive at the correct fishing speed while the net was still at the surface, and then, so to speak, ease the net down to the deeper layers; in this way, when, at the end of the haul, the maximum length of wire was out there was no fear of striking bottom. The first depth recorder tracing given in Text-fig. 4 for Station 1 shows the effect of allowing all the warp to be paid out first; on this occasion the net immediately struck the bottom.

The vertical hauls were made with the coarse international silk tow-net, the net being hauled, at the weekly station, from a depth of 28 metres. Every effort was made to haul at the same speed on each occasion, but with a hand-worked winch on a small vessel, rolling heavily, the even speed that would have been possible with a power-winch could not be attained. The margin of difference was never very great, and the speed was usually fairly closely in the neighbourhood of $\frac{1}{2}$ metre per second, but owing to the drift of the ship it was impossible to ensure that the hauls were strictly vertical.

In making the horizontal hauls for the collection of data on vertical distribution, the catches were made at six different depths, hauls of ten minutes' duration being made at each depth. The speed of towing was kept constant in the same manner as that for the oblique hauls, and in Text-fig. 5 are given the depth records obtained at the first vertical distribution station.

METHODS OF SORTING AND COUNTING.

Immediately after arrival on board the contents of the catch were poured from the enamelled tin bucket into a large glass jar, to which sufficient strong formalin was added to make a solution of about 5 per cent. in strength.

Stramin Net.—In the laboratory the entire catch was examined in a shallow glass dish, which could be moved either on to a white or black back-ground as occasion required. A small portion at a time was gone through until the entire catch had been examined. During this preliminary sorting all animals were picked out which were conspicuous either by size or colour, or were not common enough to give significant numbers by sample.

The whole catch was then transferred into a wide-mouthed bell-jar, and made up with water to 5 litres. A 500 c.c. sample, one tenth of the whole catch, was withdrawn by using a round-bottomed finger-bowl as a dipper. The organisms were thoroughly mixed until their distribution appeared as even as possible, and then a rapid dip was made, care being taken to scoop right to the bottom in order to sample any organisms that sank quickly. One dip would take up about 100 c.c. ; the operation was repeated four or five times until 500 c.c. had been transferred to a measuring cylinder, the whole catch being well stirred up between each dip. All the animals contained in this sample were then picked out and sorted.

This method has been in use regularly by one of us for some years, and the reliability of the method has been tested ; it was found that for animals whose average number of individuals in one sample was over 20, the probable error was never greater than 15 per cent. (Russell, 1925*b*, p. 775).

Coarse and Fine Silk Nets.—The catches from both these nets were treated in the same way as those of the stramin net. The complete catch was first subjected to the preliminary sorting, and then a one-tenth sample taken from the wide-mouthed bell-jar. From this sample were removed all those specimens approximating to the size of those retained by the stramin net—that is, down to the size of copepods of over about 3 mm. in length. This was necessary in order to give adequate sampling of the larger animals, which were naturally not nearly as numerous as the smaller forms in the silk net catches.

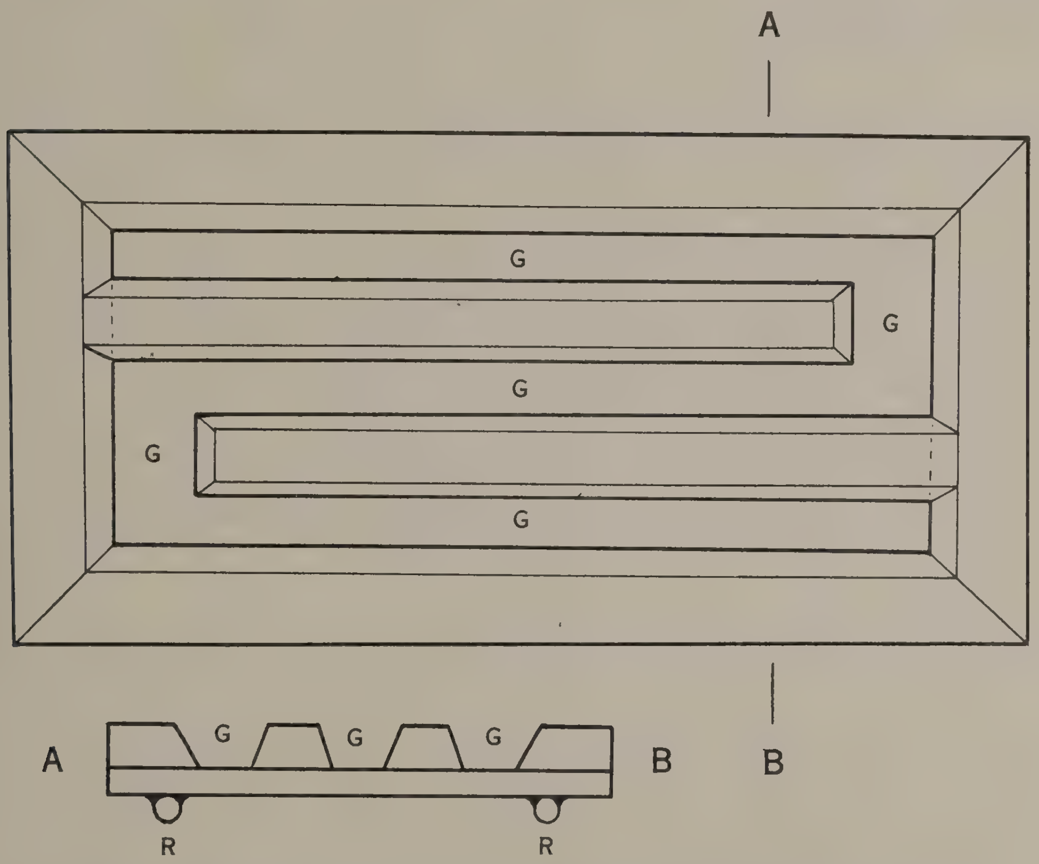
There then remained in this one-tenth sample very large numbers of these small animals, too numerous to count and too small to pick out individually in numbers in the time at our disposal. This sample was accordingly sub-sampled. The sample was poured into a finger-bowl and made up to 400 or 500 c.c., a certain amount of water having been removed from the original 500 c.c. in pipetting out the organisms. From this bowl was taken, by means of a small glass dipper, 20 or 25 c.c., according to the original sample, in much the same manner as this original one-tenth sample had been taken from the bell-jar. This sub-sample amounted then to one two-hundredth of the original catch.

The sub-sample was emptied into a counting tray, modified after that described by Bogorov (1927), and all organisms were counted under a lens or a microscope.

The counting tray consisted of a piece of thick glass 6 in. long and 3 in. in width, to which bevelled glass strips were cemented with canada balsam, so that three grooves (G) were formed, the two outer grooves being connected to the centre one at opposite ends (see Text-fig. 9, which is drawn to scale, and is natural size). The glass strips were only roughly cut, and any slight leakage in the mitred corners was sealed by the application of a little marine glue.

Animals could be rapidly counted with the aid of a needle as the eye travelled along the groove, and this tray has the added advantage that a sudden jolt does not mix up the catch. On the underside were glued two strips of glass rod (Text-fig. 9, R), which acted as rails on which the tray could be easily slid along under the lens. These rails were necessary, as it was soon found that without them a slight amount of moisture caused the flat plate glass to become almost immovably fixed to the glass stage of the dissecting microscope.

The specimens, when sorted into their various groups, were inserted in small glass tubes in 5 per cent. formalin, or 70 per cent. alcohol, according to their nature. The tubes were plugged with cotton wool, and inserted mouth downwards in honey jars filled with the preservative, and with a layer of cotton wool on the bottom. In this way, evaporation of the fluid in the honey jars could not affect the specimens in their tubes until almost the last drop was gone. When the honey jar was filled with tubes, a layer of cotton wool was placed on top and the lid screwed down. It was considered advisable to use leather disc washers, in place of rubber, which might have perished under tropical conditions. It was soon found, however, that the dressing in the leather leached out into the water and stained cotton wool and specimens black. Accordingly, before use, the washers were subjected to continuous washing for several days, and were always inserted with a disc of waxed and vaselined cardboard on their lower surfaces in order to keep moisture away from them as much as possible. In this way the tinned lids kept in excellent condition when screwed down really tight and there was no loss by evaporation.



Text-fig. 9.—Counting tray used for counting the smaller plankton animals under a lens (modified after Bogorov, 1927). G, grooves ; R, glass rods cemented on to act as rails. Top diagram, as seen from above ; lower diagram, cross section at AB. Actual size.

Collecting was so arranged that all catches could be dealt with up to date, and by the time the expedition left the sorting of the entire catches had been completed.

CARE OF NETS.

The silk and stramin nets were treated before leaving this country with copper soap preservative (Atkins, 1926). Each net was dipped for about twenty minutes in a copper soap solution, one pound of soap to one gallon of petrol, kept hot by an outer jacket of hot water.

Canvas cases were used for storage and transport of the nets, which proved an invaluable protection against damage likely to be suffered on the journeys back and forth from the laboratory to a small boat. These canvas cases were circular, one of a diameter just large enough to take the silk nets, and the other just over 1 metre in diameter to hold the stramin net. The cases can be made deep enough to hold the required number of nets, and are closed with four flaps.

For the interest of future workers the following notes on the lasting powers of the various nets is given.

Three nets of each type were taken, one of each being in use and the others kept in a tin-lined box, and occasionally inspected. In this respect the copper soap proved invaluable as a protective against damage that might be caused by cockroaches or other fabric-eating insects that are so abundant in the tropics ; no indication was ever found of damage by insects to the stored silk or stramin nets. In the writers' opinion this is a very important function of copper soap preservation ; costly silk nets, which may perish if kept for several years, can probably be kept for very long periods after copper soap treatment, secure from the ravages of insects, and at the same time, preserved from decay due to bacterial action ; but they must be kept in the dark. The nets after use were dried, if possible, in the shade, and as soon as dry were put away in their cases out of the light. They were never rinsed with fresh water (Atkins, 1926, p. 63).

The following is a record of the nets used :

No. 1 : Coarse Silk International Net.—First used on 27th July, 1928. Used for 18 half-hour oblique hauls, 12 one minute vertical hauls, and 3 vertical hauls from 180 and 250 metres. Returned to store still fit for use on 23rd October, 1928. Taken out again on 10th July, 1929, and used for 2 half-hour oblique hauls, 12 ten-minute horizontal hauls, and 1 one-minute vertical haul.

No. 2 : Coarse Silk International Net.—First used on 2nd November, 1928. Used for 35 half-hour oblique hauls, 28 one-minute vertical hauls, 4 vertical hauls from depths between 150 and 580 metres, and 6 ten-minute horizontal hauls. On 5th July, 1929, this net burst along the bottom seams during a vertical haul from 28 metres.

No. 3 : Coarse Silk International Net.—A new net was taken out for collecting on a cruise to Willis Island, but was lost overboard.

It was on account of the loss of No. 3 net that it was necessary to put No. 2 to such heavy use. This misfortune thus proved of value, as it has enabled us to discover the full life of one net. Thus No. 2 net was used 73 times during a period of eight months, from 2nd November, 1928, to 5th July, 1929, at regular intervals until it burst. The climatic conditions from November to March were at their worst, the weather being excessively humid and warm. The bursting of No. 2 made it necessary to return to No. 1, which after a previous use of 43 occasions during three months had been returned to store. There it lay, cockroach-infested, for eight months, but when taken out proved still fit for use—a striking testimony to the efficiency of the copper soap preservative.

From these facts it may be deduced that under tropical conditions, with due care, a coarse silk net (58 strands to the inch), may be expected to have a safe life of four or five months with regular use. In emergency the net would last longer than this, but for quantitative work it is probably not desirable. Three nets should suffice for one year's work of this nature, but the provision of one extra spare in case of accident is advisable.

No. 1: FINE SILK INTERNATIONAL NET.—First used on 27th July, 1928. Used for 25 half-hour oblique hauls. Returned to store on 5th December, 1928.

No. 2: FINE SILK INTERNATIONAL NET.—First used 14th December, 1928. Used for 13 half-hour oblique hauls. Returned to store on 28th February, 1929, damaged by fouling the propeller.

No. 3: FINE SILK INTERNATIONAL NET.—First used 4th March, 1929. Used for 19 half-hour oblique hauls. Last used 17th July, 1929, when collecting ceased.

Thus three fine silk nets (200 strands to the inch) proved sufficient, the number of hauls with these nets being only about half those with the coarse nets.

No. 1: STRAMIN NET.—First used on 27th July, 1928. Used for 24 half-hour oblique hauls and 2 vertical hauls from 180 and 600 metres respectively. Returned to store 5th December, 1928.

No. 2: STRAMIN NET.—First used on 14th December, 1928. Used for 10 half-hour oblique hauls. Returned to store before an extended cruise on 18th February, 1929.

No. 3: STRAMIN NET.—First used on 26th February, 1929. Used for 21 half-hour oblique hauls. Last used on 17th July, 1929, when collecting ceased.

The stramin nets would probably have lasted considerably longer. They were not kept too long in use so that their quantitative value should not be lost. Unlike the meshes of the silk nets, whose threads are interwoven, the meshes on the stramin tend in time to open.

REFERENCES.

ATKINS, W. R. G. 1926. Notes on the Preservation of Fishing Nets by Means of Copper Soaps. Journ. Mar. Biol. Assoc. U.K., N.S. XIV, pp. 63–69; 1 text illust.

BOGOROV, B. G. 1927. Zur Methodik der Bearbeitung des Planktons. (Eine neue Kammer zur Bearbeitung des Zooplanktons). Russk. gidrobiol. Zh. [=Russ. hydrobiol. Z. Saratov.] VI, pp. 193–198; 2 text illust.

KEMP, STANLEY, and HARDY, A. C. 1929. The "Discovery" Investigations, Objects, Equipment and Methods. Part II: The Ships, their Equipment, and the Methods used in Research. "Discovery" Reports, Cambridge, I, pp. 151–222, pls. 7–17, text illust.

KNUDSEN, MARTIN. 1923. Some New Oceanographical Instruments. Pub. Circ. Cons. Explor. Mer. No. 77, pp. 16, text illust.

KÜNNE, CL. 1929. Vergleich der Fangfähigkeit verschiedener Modelle von Plankton-netzen. Rapp. Cons. Explor. Mer. LIX, pp. 37, 3 text illust.

OSTENFELD, C. H., and JESPERSEN, P. 1924. Standard Net for Plankton Collections. Pub. Circ. Cons. Explor. Mer. No. 84, pp. 16, text illust.

RUSSELL, F. S. 1925*a*. A Releasing Apparatus for Horizontally Towed Plankton Nets. Journ. Mar. Biol. Assoc. U.K., N.S. XIII, pp. 673–677, text illust.

—— 1925*b*. The Vertical Distribution of Marine Macroplankton: An Observation on Diurnal Changes. Journ. Mar. Biol. Assoc. U.K., N.S. XIII, pp. 769–809, 1 pl., text illust.

—— 1926. The Vertical Distribution of Marine Macroplankton: III. Diurnal Observations on the Pelagic Young of Teleostean Fishes in the Plymouth Area. Journ. Mar. Biol. Assoc. U.K., N.S. XIV, pp. 387–414, text illust.

—— 1928. A Net for Catching Plankton near the Bottom. Journ. Mar. Biol. Assoc. U.K., N.S. XV, pp. 105–108, 2 text illust.

List of

ABBREVIATIONS
Under "Net":
Stramin = One metre stramin net.
Fine = Fine international silk net.
Coarse = Coarse international silk net.

Station number.	Date.	Position.	Depth in metres.	Time.	Net.	Haul.	Maximum length of wire out (metres).	Length of wire paid out at intervals (metres).
	1928.							
1	July 27th	2 mi. N.E.	31	9.43–10.13 a.m.	Stramin	Oblique	40	4
	,, ,,	,,	,,	10.35–11.05 ,,	Fine and coarse	,,	40	4
	,, ,,	,,	,,	11.30 a.m.–12.00 noon	,, ,,	,,	30	4
2	,, 30th	3 mi. E.	,,	9.48–10.18 a.m.	,, ,,	,,	30	3
	,, ,,	,,	,,	10.43–11.13 ,,	Stramin	,,	34	4
3	Aug. 4th	,,	32	9.19–9.49 ,,	,,	,,	45	5
	,, ,,	,,	,,	10.09–10.39 ,,	Fine and coarse	,,	45	5
4	,, 7th	1 mi. N.	16	10.20–10.30 ,,	Coarse	Horizontal	..	..
	,, ,,	,,	,,	10.38–10.48 ,,	,,	,,	10	..
5	,, 11th	3 mi. E.	32	9.17–9.47 ,,	Stramin	Oblique	40	5
	,, ,,	,,	,,	10.10–10.40 ,,	Fine and coarse	,,	40	5
6	,, 17th	,,	,,	12.38–1.08 p.m.	Stramin	,,	40	5
	,, ,,	,,	,,	1.28–1.58 ,,	Fine and coarse	,,	40	5
	,, ,,	,,	,,	2.15 p.m.	Coarse	Vertical	25	..
7	,, 22nd	,,	,,	9.35–10.04 a.m.	Stramin	Oblique	40	5
	,, ,,	,,	,,	10.31–11.01 ,,	Fine and coarse	,,	40	5
	,, ,,	,,	,,	11.22 a.m.	Coarse	Vertical	28	..
8	,, 24th	16° 30′ S. 145° 52′ E. (in Trinity Opening)	45	9.52–10.22 a.m.	Stramin	Oblique	60	10 and 5
	,, ,,	Ditto	,,	10.52–11.22 ,,	Fine and coarse	,,	60	10 and 5
	,, ,,	,,	,,	11.50 a.m.	Coarse	Vertical	40	..
9	,, 31st	3 mi. E.	32	11.30 a.m.–12.00 noon	Stramin	Oblique	40	5
	,, ,,	,,	,,	12.25–12.55 p.m.	Fine and coarse	,,	40	5
	,, ,,	,,	,,	1.10 p.m.	Coarse	Vertical	28	..
10	Sept. 4th	,,	,,	9.27–9.57 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.17–10.47 ,,	Fine and coarse	,,	36	6
	,, ,,	,,	,,	11.05 a.m.	Coarse	Vertical	28	..
11	,, 6th	16° 24′ S. 145° 52′ E. (in Trinity Opening)	61	9.50–10.21 a.m.	Stramin	Oblique	80	10 and 15
	,, ,,	Ditto	,,	10.45–11.15 ,,	Fine and coarse	,,	80	10 and 15
	,, ,,	,,	,,	11.35 a.m.	Coarse	Vertical	55	..
12	,, 11th	3 mi. E.	32	9.28–9.58 a.m.	Stramin	Oblique	42	6
	,, ,,	,,	,,	10.15–10.45 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	11.10 a.m.	Coarse	Vertical	28	..
13	,, 20th	3 mi. E.	,,	10.10–10.40 a.m.	Stramin	Oblique	36	6
	,, ,,	,,	,,	10.55–11.25 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	11.40 a.m.	Coarse	Vertical	28	..
14	,, 26th	,,	,,	9.20–9.50 a.m.	Stramin	Oblique	54	6
	,, ,,	,,	,,	10.08–10.38 ,,	Fine and coarse	,,	54	6
	,, ,,	,,	,,	11.07 a.m.	Coarse	Vertical	28	..
15	Oct. 2nd	,,	,,	9.12–9.42 a.m.	Stramin	Oblique	32	6 and 2
	,, ,,	,,	,,	10.00–10.30 ,,	Fine and coarse	,,	42	6
	,, ,,	,,	,,	10.50 a.m.	Coarse	Vertical	28	..
16	,, 3rd	,,	,,	10.13–10.23 a.m.	Closing coarse	Horizontal	..	..
	,, ,,	,,	,,	10.33–10.43 ,,	,, ,,	,,	10	..
	,, ,,	,,	,,	11.07–11.17 ,,	,, ,,	,,	20	..
	,, ,,	,,	,,	11.29–11.39 ,,	,, ,,	,,	30	..
	,, ,,	,,	,,	11.46–11.56 ,,	,, ,,	,,	40	..
	,, ,,	,,	,,	12.17–12.27 p.m.	,, ,,	,,	25	..
17	,, 8th	,,	,,	2.45–3.00 ,,	Stramin	Oblique	24	6
18	,, 15th	,,	,,	9.48–10.18 a.m.	,,	,,	48	6
	,, ,,	,,	,,	10.40–11.10 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	11.25 a.m.	Coarse	Vertical	28	..

STATIONS.

Under "Position":

3 mi. E. = The weekly station 3 miles East of Low Isles.
2 mi. N.E. = 2 miles north-east of Low Isles.
1 mi. N. = 1 mile north of Low Isles.

Station number.	Maximum depth fished by net (metres).	Secchi disc (metres)	Temperature (° C., 10 m.).	Salinity °/oo (10 m.).	Wind.*	Remarks.
1	18	6	21·90°	..	..	Sunny; sea calm; engine.
	Bottom	,,	,,	..	..	,, ,, ,, net touched bottom.
	25	,,	,,	..	..	11.52 a.m. hauled in 10 m.; 11.56 a.m. hauled in 10 m.
2	17	5½	22·58°	35·16	S.E.	Sunny; sea lumpy; sailing with jib.
	14	,,	,,	,,	,,	,, ,, ,, ,, ,,
3	15	10	22·28°	35·08	,,	,, ,, ,, ,, ,,
	23·5	,,	,,	,,	,,	,, ,, ,, ,, ,,
4	Surface	..	..	..	,,	Worked in shelter of island; fresh breeze.
	3·5 av.	..	..	..	,,	,, ,, ,, ,,
5	19	8	21·52°	34·91	S.E. 4	Sunny; light clouds; sea lumpy.
	20	,,	,,	,,	,,	,, ,, ,,
6	15	..	..	..	E.S.E. 4	Dull, with occasional sun; swell.
	15	..	..	..	,,	,,
	..	..	..	..	,,	,, 55 seconds' hauling.
7	21	9	22·42°	35·24	S.S.E. 4	Sunny; wind dropping; sea slight.
	20·5	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	,, ,, ,, 42 seconds' hauling.
8	25·5	30	23·22°	35·30	S.S.W. 2	,, sea lumpy.
	28·5	,,	,,	,,	,,	,, ,,
	..	,,	,,	,,	,,	,, ,, 1 min. 33 sec. hauling.
9	16·5	6½	23·0°	35·19	S.S.E. 4	Cloudy; sea moderate; fresh breeze.
	17	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	,, ,, 50 seconds' hauling.
10	24·5	17	23·45°	35·26	S.S.W. 2	Bright sun; calm to lumpy.
	28	,,	,,	,,	,,	,, 10.38 a.m. hauled in to 20 m.; too slow.
	..	,,	,,	,,	,,	,, 50 seconds' hauling.
11	34·5	23	23·91°	35·25	S. 2	Cloudy; wind fresh; sea lumpy.
	33	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	,, ,, 1 min. 55 sec. hauling.
12	23	20	24·13°	35·27	S.S.E. 2	Sea calm to lumpy; slight haze; sailing with jib and mainsail.
	27·5	,,	,,	,,	,,	,, ,, ,, fine net touched bottom at 27·5 m.
	..	,,	,,	,,	,,	,, ,, ,, 53 seconds' hauling.
13	22	9	24·53°	35·30	S. 3	Slight breeze; sunny; sea calm to lumpy; mainsail used 10.25 a.m.
	19	,,	,,	,,	,,	,, ,, ,, ,, ,,
	..	,,	,,	,,	,,	52 seconds' hauling.
14	19	13	25·11°	35·35	E.S.E. 3	Sunny; light clouds; calm.
	25	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	42 seconds' hauling.
15	21	9½	25·10°	35·38	S. 2	Sunny; calm; 9.30 a.m. hauled in 10 m. and used engine.
	21	,,	,,	,,	,,	10.21 a.m. hauled in 10 m.
	..	,,	,,	,,	,,	59 seconds' hauling.
16	Surface	10	..	..	W.S.W. 2	Sunny; glass calm.
	3·1 av.†	,,	..	..	,,	,, ,,
	8 ,,	,,	..	..	,,	,, ,,
	12·5 ,,	,,	..	..	,,	,, ,,
	16·5 ,,	,,	..	..	,,	,, ,,
	11·1 ,,	,,	..	..	,,	,, ,,
17	12·5	12	25·40°	35·35	S.E. 2	,, calm; wire slipping on drum.
18	25	7	25·93	35·41	S.E. 3	,, to dull; fresh breeze; sea lumpy.
	25·5	,,	,,	,,	,,	,, ,, ,, ,,
	..	,,	,,	,,	,,	,, ,, 62 seconds' hauling.

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* When the force of the wind is given it refers to the 9 a.m. reading at Low Isles.
† av. = Average depth throughout haul.

LIST OF

Station number.	Date.	Position.	Depth in metres.	Time.	Net.	Haul.	Maximum length of wire out (metres).	Length of wire paid out at intervals (metres).
	1928.							
19	Oct. 20th	16° 20′ S. 146° 3′ E. (outside Trinity Opening)	225	11.20–11.32 a.m.	Stramin	Vertical	180	..
	,, ,,	Ditto	,,	11.42 a.m.	Coarse	,,	180	..
	,, ,,	,,	,,	12.33–12.49 p.m.	,,	,,	180	..
	,, ,,	,,	,,	1.00 p.m.	1 m. coarse	,,	180	..
20	,, ,,	16° 19′ S. 146° 7′ E.	>600	4.10 p.m.	Coarse	Vertical	250	..
21	,, 22nd	3 mi. E.	32	8.40–9.10 p.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	7.46–8.16 ,,	Fine and coarse	,,	48	6
22	,, 23rd	,,	,,	8.49–9.19 a.m.	Stramin	,,	48	6
	,, ,,	,,	,,	9.35–10.05 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	10.20 a.m.	Coarse	Vertical	28	..
23	Nov. 2nd	,,	,,	9.27–9.57 a.m.	Fine and coarse	Oblique	48	6
	,, ,,	,,	,,	10.22–10.52 ,,	Stramin	,,	48	6
	,, ,,	,,	,,	11.12 a.m.	Coarse	Vertical	28	..
24	,, 6th	,,	,,	9.15–9.46 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.05–10.35 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	10.50 a.m.	Coarse	Vertical	28	..
25	,, 16th	,,	,,	9.34–10.04 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.27–10.57 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	11.15 a.m.	Coarse	Vertical	28	..
26	,, 19th	16° 24′ S. 145° 53½′ E. (in Trinity Opening)	57	9.10–9.39 a.m.	Stramin	Oblique	80	10 and 15
	,, ,,	Ditto	,,	9.54–10.24 ,,	Fine and coarse	,,	80	10 and 15
	,, ,,	,,	,,	10.53 a.m.	Coarse	Vertical	50	..
27	,, 21st	3 mi. E.	32	9.00–9.30 a.m.	Stramin	Oblique	42	6
	,, ,,	,,	,,	9.48–10.18 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	10.35 a.m.	Coarse	Vertical	28	..
28	,, 23rd	16° 19′ S. 146° 5′ E. (outside Trinity Opening)	>600	2.00–2.18 p.m.	,,	,,	580	..
	,, ,,	Ditto	,,	2.43–3.10 ,,	Stramin	,,	600	..
9	,, 24th	16° 17′ S. 146° 2′ E.	*ca.* 200	2.17 p.m.	Bottom stramin	Bottom	..	..
30	,, 28th	3 mi. E.	32	11.10–11.41 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	12.20 p.m.	Coarse	Vertical	28	..
30*a*	,, 29th	,,	,,	11.09–11.39 a.m.	Fine and coarse	Oblique	48	6
31	Dec. 2nd	,,	,,	2.50 p.m.	Bottom stramin	Bottom	..	..
32	,, 5th	,,	,,	9.00 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.08–9.38 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.00–10.30 ,,	Fine and coarse	,,	48	6
33	,, 13th	,,	,,	2.18–2.48 p.m.	,, ,,	,,	48	6
	,, ,,	,,	,,	3.17–3.47 ,,	Stramin	,,	48	6
	,, ,,	,,	31	4.20 p.m.	Coarse	Vertical	27	..
34	,, 19th	,,	32	7.53–8.23 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	8.45–9.15 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	9.26 a.m.	Coarse	Vertical	28	..
35	,, 27th	,,	,,	10.04 ,,	,,	,,	28	..
	,, ,,	,,	,,	10.18–10.48 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	11.10–11.39 ,,	Fine and coarse	,,	48	6
	1929.							
36	Jan. 4th	3 mi. E.	32	10.20–10.50 a.m.	Stramin	,,	48	6
	,, ,,	,,	,,	11.40 a.m.–12.10 p.m.	Fine and coarse	,,	48	6
37	,, 14th	,,	31	8.32 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	8.45–9.15 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	9.40–10.10 ,,	Fine and coarse	,,	48	6
38	,, 21st	,,	32	9.25 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.35–10.05 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.23–10.53 ,,	Fine and coarse	,,	48	6
39	,, 30th	,,	31	9.30 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.40–10.20 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.30–11.00 ,,	Fine and coarse	,,	48	6
40	Feb. 6th	,,	32	2.50–3.20 p.m.	Stramin	,,	48	6
	,, ,,	,,	,,	3.50–4.20 ,,	Fine and coarse	,,	48	6
	,, ,,	,,	,,	4.50 p.m.	Coarse	Vertical	28	..

STATIONS—*continued.*

Station number.	Maximum depth fished by net (metres).	Secchi disc (metres)	Temperature (°C., 10 m.).	Salinity °/oo (10 m.).	Wind.	Remarks.
19	..	36	26·05°	35·24	E.N.E. 2	Sunny; light clouds; calm, but swell; 3½ minutes down; 8 minutes up.
	..	,,	,,	,,	,,	Net fouled wire going down.
	..	,,	,,	,,	,,	9 min. going down ; 7 min. 20 sec. up.
	..	,,	,,	,,	,,	6 min. going down ; ? up.
20	..	..	..	..	N.W. 1	10 minutes going down ; ? up.
21	22	..	..	..	W.N.W. 1	Flat calm.
	20·5	..	..	..	,,	,,
22	20	20	26·50°	35·30	,,	Sunny ; calm.
	20·5	,,	,,	,,	,,	,, ,,
	..	,,	,,	,,	,,	,, ,, 50 seconds' hauling.
23	25·5	18	27·24°	35·30	N.E. 2	,, light clouds; calm ; 9.53 a.m. hauled in 6 m. ; new coarse net.
	24	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	,, ,, ,, 50 seconds' hauling.
24	15·5	17·5	27·33°	35·26	E.S.E. 3	Wind rose from calm to 20 m.p.h. Cloudy.
	22·5	,,	,,	,,	,,	Squally ; choppy sea.
	..	,,	,,	,,	,,	61 seconds' hauling.
25	*24**	5·5	26·57°	35·06	S.S.E. 3	Sunny; light clouds; fairly calm.
	23	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	,, ,, ,, 51 seconds' hauling.
26	*34*	11	26·61°	35·17	S. 2	,, high clouds; calm, with swell; 9.20 a.m. engine used.
	33	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	,, ,, 1 min. 40 sec. hauling.
27	*22·5*	16·5	26·90°	35·21	S.S.E. 2	,, light breeze.
	23	,,	,,	,,	,,	,, ,, ,, 10.03 a.m. engine used.
	..	,,	,,	,,	,,	,, ,, ,, 1 min. 8 sec. hauling.
28	..	..	26·91°†	35·08†	S.W. 1	,, calm with swell.
	..	..	,,	,,	,,	,, ,, ,,
29	Bottom	..	..	..	W. 1	,, calm with swell; 16 minutes on bottom; 19 minutes coming up.
30	*17*	12	27·34°	35·16	S.E. 5	Cloudy ; sea rough.
	..	,,	,,	,,	,,	,, ,, 1 min. 3 sec. hauling ; bad drift.
30*a*	*20*	9	..	..	S.E. 4	Sea choppy.
31	Bottom	..	..	..	S.S.E. 3	Calm ; sunny ; 11½ minutes on bottom.
32	..	16	27·57°	35·28	S.W. 2	,, 56 seconds' hauling.
	22·5	,,	,,	,,	,,	,, engine used.
	23·5	,,	,,	,,	,,	,, ,,
33	*18*	11	28·17°	35·24	S.S.E. 3	New fine net.
	21·5	,,	,,	,,	,,	New net.
	..	,,	,,	,,	,,	55 seconds' hauling.
34	*22*	20	28·42°	35·06	W.N.W. 1	Sunny; calm ; engine used.
	24	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	53 seconds' hauling.
35	..	17	29·43°	35·05	S.W. 1	Sunny ; calm ; 1 min. 2 sec. hauling.
	23	,,	,,	,,	,,	,, ,, engine used.
	23	,,	,,	,,	,,	,, ,, ,,
36	*22·5*	10	28·56°	34·95	S.S.W. 3	Overcast sky ; choppy ; irregular breeze.
	23	,,	,,	,,	,,	,, ,, ,, ,, ,,
37	..	15·5	28·47°	34·43	W. 1	,, ,, calm; 55 seconds' hauling.
	21	,,	,,	,,	,,	..
	26	,,	,,	,,	,,	10.06 a.m. used engine.
38	..	19	28·94°	34·50	E.S.E. 2	Overcast sky; slight swell; 55 seconds' hauling.
	23	,,	,,	,,	,,	9.42 a.m. used engine.
	24	,,	,,	,,	,,	
39	..	14	28·89°	33·82	S.E. 1	Calm ; sunny ; 55 seconds' hauling.
	22·5	,,	,,	,,	,,	,, ,, used engine.
	23	,,	,,	,,	,,	,, ,, ,,
40	*19*	16·5	..	..	E.S.E. 3	Fine ; used engine partly.
	23·5	,,	..	..	N.E.	N.E. squall with heavy rain.
	..	,,	..	..	,,	,, 55 seconds' hauling.

* From this date onwards the maximum depth fished is estimated from the angle readings and given in italics.

† 5 metres.

LIST OF

Station number.	Date.	Position.	Depth in metres.	Time.	Net.	Haul.	Maximum length of wire out (metres).	Length of wire paid out at intervals (metres).
41	1929. Feb. 13th	3 mi. E.	32	9.10 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.20–9.50 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.5–10.35 ,,	Fine and coarse	,,	48	6
42	,, 18th	,,	,,	9.00 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.15–9.45 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.05–10.35 ,,	Fine and coarse	,,	48	6
43	,, 26th	15° 16′ S. 144° 26½′ E. (off Cape Bedford)	30	12.30–1.00 p.m.	Stramin	,,	40	5
	,, ,,	Ditto	,,	1.20–1.50 ,,	Fine and coarse	,,	40	5
44	,, 27th	14° 44′ S. 145° 27½′ E. (off Lizard Island)	31	12.00–12.30 ,,	Stramin	Oblique	48	6
	,, ,,	Ditto	,,	12.45–1.15 ,,	Fine and coarse	,,	48	6
45	,, 28th	14° 31′ S. 145° 35′ E. (outside Cook's Passage)	>600	12.15–12.30 ,,	Stramin	Vertical	500	..
	,, ,,	Ditto	,,	1.00–1.12 ,,	Coarse	,,	500	..
46	,, ,,	14° 32′ S. 145° 32′ E. (inside Cook's Passage)	33	2.00–2.29 ,,	Stramin	Oblique	48	6
	,, ,,	Ditto	,,	2.50–3.19 ,,	Fine and coarse	,,	48	6
47	Mar. 4th	3 mi. E.	31	9.00 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.15–9.45 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.00–10.30 ,,	Fine and coarse	,,	48	6
48	,, 15th	,,	30	12.45 p.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	1.15–1.45 p.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	2.00–2.30 ,,	Fine and coarse	,,	48	6
49	,, 17th	15° 47′ S. 145° 47′ E. (inside Papuan Pass)	46	12.25–12.56 ,,	Stramin	,,	72	9
	,, ,,	Ditto	,,	1.10–1.40 ,,	Fine and coarse	,,	72	9
50	,, 18th	(outside Papuan Pass)	>400	9.40–9.52 a.m.	Stramin	Vertical	400	..
	,, ,,	Ditto	,,	10.45–10.50 ,,	,,	,,	170	..
	,, ,,	,,	,,	11.25–11.30 ,,	Coarse	,,	150	..
51	,, 25th	3 mi. E.	33	8.15 a.m.	,,	,,	28	..
	,, ,,	,,	,,	10.15–10.45 a.m.	Fine and coarse	Oblique	48	6
	,, ,,	,,	,,	11.00–11.30 ,,	Stramin	,,	48	6
52	April 6th	,,	32	10.00 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	10.15–10.45 ,,	Stramin	Oblique	48	6
	,, ,,	,,	,,	11.15–11.45 ,,	Fine and coarse	,,	48	6
53	,, 13th	,,	,,	9.15 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.45–10.15 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	11.00–11.30 ,,	Fine and coarse	,,	48	6
54	,, 20th	,,	31	11.45 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	12.00–12.30 p.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	1.10–1.40 ,,	Fine and coarse	,,	48	6
55	,, 26th	,,	,,	9.15 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.25–9.55 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.30–11.00 ,,	Fine and coarse	,,	48	6
56	May 7th	,,	,,	11.00–11.33 ,,	Stramin	,,	48	6
	,, ,,	,,	,,	12.00–12.30 p.m.	Fine and coarse	,,	48	6
	,, ,,	,,	,,	1.00 p.m.	Coarse	Vertical	28	..
57	,, 18th	,,	32	8.45 a.m.	,,	,,	28	..
	,, ,,	,,	,,	9.00–9.30 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.00–10.30 ,,	Fine and coarse	,,	48	6
58	,, 25th	,,	,,	9.15 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.45–10.16 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.30–11.00 ,,	Fine and coarse	,,	48	6
59	,, 31st	,,	,,	8.45 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.15–9.45 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.15–10.45 ,,	Fine and coarse	,,	48	6
60	June 7th	,,	,,	9.15 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	9.40–10.10 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	10.40–11.20 ,,	Fine and coarse	,,	48	6

STATIONS—*continued.*

Station number.	Maximum depth fished by net (metres).	Secchi disc (metres)	Temperature (° C., 10 m.).	Salinity °/₀₀ (10 m.).	Wind.	Remarks.
41	..	25	28·64°	33·63	..	Calm; sunny; light clouds; 59 seconds' hauling.
	22·5	,,	,,	,,	..	,, ,, ,, used engine.
	24	,,	,,	,,	..	,, ,, ,, ,,
42	..	22·5	29·00°	33·63	W. 1	,, ,, 55 seconds' hauling.
	23	,,	,,	,,	,,	,, ,, used engine.
	24	,,	,,	,,	,,	,, ,, ,,
43	*24*	7	28·81°	34·05	N.	Strong northerly breeze; light clouds.
	20	,,	,,	,,	,,	,, ,, ,,
44	*17*	9	27·97°	34·44	Light N.	Calm. Rainy to dull. Engine used.
	23·5	,,	,,	,,	,,	,, ,, ,, ,,
45	..	14	,,	34·53	Light N.E.	Considerable swell. Rain squalls; dull; 36 m. wire tangled.
	..	,,	,,	,,	,,	,, ,, ,, ,,
46	*22·5*	12	27·61°	34·39	N.W.	Fierce rain-squall from N.W.; 3-knot tide through Passage.
	23	,,	,,	,,	,,	,, ,, ,, the bottom was living coral.
47	..	16	28·42°	34·02	W. 1	Sunny; calm; 58 seconds' hauling.
	22·5	,,	,,	,,	,,	,, ,, used engine.
	23·5	,,	,,	,,	,,	,, ,, ,, new fine net.
48	..	3·5	28·27°	33·49	S.E. 3	Clouds; sea moderate; 57 seconds' hauling.
	18	,,	,,	,,	,,	,, ,, used motor.
	25·5	,,	,,	,,	,,	,,
49	*30*	14	28·23°	34·54	S.E.	Fine; light breeze; sea lumpy.
	31	,,	,,	,,	,,	,, ,,
50	..	28	28·24°	34·56	..	Dead calm; sunny.
	..	,,	,,	,,	..	,, ,,
	..	,,	,,	,,	..	,, ,,
51	..	4½	27·68°	32·91	E. 1	Sunny; light clouds; sea lumpy; 57 seconds' hauling.
	24	,,	,,	,,	,,	,, ,, ,, engine used.
	22·5	,,	,,	,,	,,	,, ,, ,,
52	..	13	27·62°*	32·55*	S.E. 4	Dull; rather rough; 45 seconds' hauling.
	16·5	,,	,,	,,	,,	,, ,, drifting without sail.
	23·5	,,	,,	,,	,,	,, ,,
53	..	8	26·90°	33·59	S.S.E. 3.	Sunny; sea slight to moderate; 73 seconds' hauling.
	18	,,	,,	,,	,,	,, ,, ,,
	23·5	,,	,,	,,	,,	,, ,, ,,
54	..	4	25·96°	33·56	S.E. 4	Overcast sky; rough; 58 seconds' hauling.
	16·5	,,	,,	,,	,,	,, ,, drifting without sail.
	21	,,	,,	,,	,,	,, ,, ,, ,,
55	..	18	26·52°	34·07	S.W. 2	Sunny; calm; 60 seconds' hauling.
	24	,,	,,	,,	,,	,, ,, used engine.
	24	,,	,,	,,	,,	,, ,, ,,
56	*8*	5	25·27°	34·23	S.E. 4	,, light clouds; rough.
	15	,,	,,	,,	,,	,, ,, ,,
	..	,,	,,	,,	,,	,, ,, ,, 57 seconds' hauling.
57	..	12	24·68°	34·44	W. 2	Calm; sunny; 60 seconds' hauling.
	23	,,	,,	,,	,,	,, ,, used engine.
	24·5	,,	,,	,,	,,	,, ,, ,,
58	..	7	24·09°	34·37	S.E. 2	Sunny; light clouds; 62 seconds' hauling.
	22	,,	,,	,,	,,	,, ,, light wind.
	22	,,	,,	,,	,,	,, ,, ,,
59	..	6·5	23·63°	34·53	S.S.E. 3	Overcast; moderate swell; 57 seconds' hauling.
	20·5	,,	,,	,,	,,	,, ,,
	22	,,	,,	,,	,,	,, ,,
60	..	13	23·99°	34·93	S.E. 3	Sunny; moderate swell; 67 seconds' hauling.
	22·5	,,	,,	,,	,,	,, ,,
	23·5	,,	,,	,,	,,	,, ,,

* Temperature and salinity observations made on April 5th.

List of

Station number.	Date.	Position.	Depth in metres.	Time.	Net.	Haul.	Maximum length of wire out (metres).	Length of wire paid out at intervals (metres.)
	1929.							
61	June 14th	3 mi. E.	31	1.30 p.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	1.45–2.15 p.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	3.00–3.30 ,,	Fine and coarse	,,	48	6
62	,, 15th	,,	32	11.20–11.30 a.m.	Coarse closing	Horizontal	..	..
	,, ,,	,,	,,	11.45–11.55 ,,	,, ,,	,,	10	..
	,, ,,	,,	,,	12.05–12.15 p.m.	,, ,,	,,	20	..
	,, ,,	,,	,,	12.30–12.40 ,,	,, ,,	,,	30	..
	,, ,,	,,	,,	1.07–1.17 ,,	,, ,,	,,	40	..
	,, ,,	,,	,,	1.35–1.45 ,,	,, ,,	,,	50	..
63	,, 24th	,,	,,	11.45 a.m.–12.15 p.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	1.00–1.30 p.m.	Fine and coarse	,,	48	6
64	July 5th	,,	,,	10.30–11.00 a.m.	Fine and stramin	,,	48	6
65	,, 10th	,,	,,	9.00–9.10 p.m.	Coarse closing	Horizontal	..	..
	,, ,,	,,	,,	9.30–9.41 ,,	,, ,,	,,	10	..
	,, ,,	,,	,,	9.55–10.07 ,,	,, ,,	,,	20	..
	,, ,,	,,	,,	10.20–10.30 ,,	,, ,,	,,	30	..
	,, ,,	,,	,,	10.50–11.00 ,,	,, ,,	,,	40	..
	,, ,,	,,	,,	11.15–11.25 ,,	,, ,,	,,	50	..
66	,, 11th	,,	30	10.50 a.m.	Coarse	Vertical	28	..
	,, ,,	,,	,,	11.00–11.30 a.m.	Stramin	Oblique	48	6
	,, ,,	,,	,,	11.50 a.m.–12.20 p.m.	Fine and coarse	,,	48	6
67	,, 17th	,,	32	9.40–10.10 a.m.	Stramin	,,	48	6
	,, ,,	,,	,,	10.30–11.00 ,,	Fine and coarse	,,	48	6
68	,, 18th	,,	,,	10.30–10.40 ,,	Coarse closing	Horizontal	..	..
	,, ,,	,,	,,	10.55–11.05 ,,	,, ,,	,,	10	..
	,, ,,	,,	,,	11.20–11.30 ,,	,, ,,	,,	20	..
	,, ,,	,,	,,	11.50–12.00 noon	,, ,,	,,	30	..
	,, ,,	,,	,,	12.15–12.25 p.m.	,, ,,	,,	40	..
	,, ,,	,,	,,	12.45–12.55 ,,	,, ,,	,,	50	..

Reef Flat Plankton

Collections taken in small coarse tow-net (30 cm. diameter at mouth, 50 strands

1928.		
Aug. 10th	4.10 p.m.	
,, 16th	11.45 a.m.	
,, 25th	5.30 p.m.	
Sept. 2nd	9.15 a.m.	
,, 10th	4.55 p.m.	
,, 17th	8.45 a.m.	
,, 19th	2.40 p.m.	
,, 25th	5.02 ,,	
,, 28th	7.00 a.m.	Coarse international.
,, 29th	9.45 ,,	
Oct. 1st	7.55 p.m.	

1928.	
Oct. 7th	5.5 p.m.
,, 12th	8.40 a.m.
,, 22nd	4.10 p.m.
,, 30th	9.55 a.m.
Nov. 8th	5.10 p.m.
,, 13th	5.20 ,,
,, 25th	9.30 a.m.
Dec. 3rd	4.00 p.m.
,, 10th	11.10 a.m.
,, 15th	2.35 p.m.
,, 28th	2.00 ,,

STATIONS—*continued.*

Station number.	Maximum depth fished by net (metres).	Secchi disc (metres)	Temperature (° C., 10m.).	Salinity °/₀₀ (10 m.).	Wind.	Remarks.
61	..	5·5	22·55°	34·55	S. 2	Fresh breeze by 1 p.m. from S.E.; rough; 60 seconds' hauling.
	16·5	,,	,,	,,	,,	,, ,, ,, ,, drifting without sails.
	22	,,	,,	,,	,,	,, ,, ,, ,, ,, ,,
62	Surface	6	..	..	S.W. 1	Calm; sunny; engine used.
	4 av.*	,,	..	..	,,	,, ,, ,,
	7·5 ,,	,,	..	..	,,	,, ,, ,,
	12·5 ,,	,,	..	..	,,	,, ,, ,,
	16 ,,	,,	..	..	,,	,, ,, ,,
	21 ,,	,,	..	..	,,	,, ,, ,,
63	*15*	8	22·10°	34·70	S.S.E. 4	Sunny; light clouds; rough; drifting without sail.
	18	,,	,,	,,	,,	,, ,, ,, ,, ,,
64	*17·5*	8	21·91°	35·10	S.E. 4	,, fresh breeze; rather rough; drifting without sail; coarse tow-net burst during vertical haul.
65	Surface	..	..	..	S.S.W. 2	..
	3·7 av.*	..	..	..	,,	Net did not close.
	8 ,,	..	..	..	,,	,, ,,
	12·5 ,,	..	..	..	,,	..
	15·5 ,,	..	..	..	,,	..
	20·7 ,,	..	..	..	,,	..
66	..	10	21·41°	34·85	,,	Sunny; calm; 60 seconds' hauling.
	22	,,	,,	,,	,,	,, ,, engine used partly.
	23·5	,,	,,	,,	,,	,, ,, ,, ,, ,,
67	*22·5*	9	21·27°	35·02	,,	,, light clouds; lumpy; engine used partly.
	23·5	,,	,,	,,	,,	,, ,, ,, ,, ,,
68	Surface	9·5	..	..	,,	,, calm; engine used.
	3·5 av.*	,,	..	..	,,	,, ,, ,,
	7·5 ,,	,,	..	..	,,	,, ,, ,,
	12 ,,	,,	..	..	,,	,, ,, ,,
	16·5 ,,	,,	..	..	,,	,, ,, ,,
	20·7 ,,	,,	..	..	,,	,, ,, ,,

* av. = Average depth throughout haul.

COLLECTIONS.

to 1 inch) from rowing-boat over reef flat at high water. Ten-minute hauls.

1929.			
Jan. 5th	.	3.15 p.m.	
Feb. 9th	.	12.15 ,,	
,, 18th	.	10.00 ,,	
Mar. 1st	.	3.00 ,,	Three Isles. 15° 7′ S. 145° 25′ E. (5 minutes).
,, 17th	.	12.35 ,,	
,, 26th	.	11.40 a.m.	
April 1st	.	10.20 ,,	
,, 9th	.	9.40 ,,	

1929.		
April 18th	.	10.00 a.m.
,, 25th	.	9.30 ,,
May 8th	.	9.45 ,,
,, 16th	.	4.15 p.m.
,, 22nd	.	10.00 a.m.
,, 23rd	.	7.40 p.m.
June 8th	.	10.00 a.m.
,, 28th	.	9.40 p.m.
July 1st	.	10.10 a.m.
,, 9th	.	10.40 ,,

DESCRIPTION OF PLATE I.

Fig. 1.—Photo showing attachment of depth-recording instrument in front of net. In this photo the coarse international silk tow-net is shown; note the absence of coarse netting, the silk being attached direct to the ring by a calico band. (See text, p. 7.)

Fig. 2.—The 1 metre stramin net coming up.

Fig. 3.—Harry and Paul working the plankton winch.

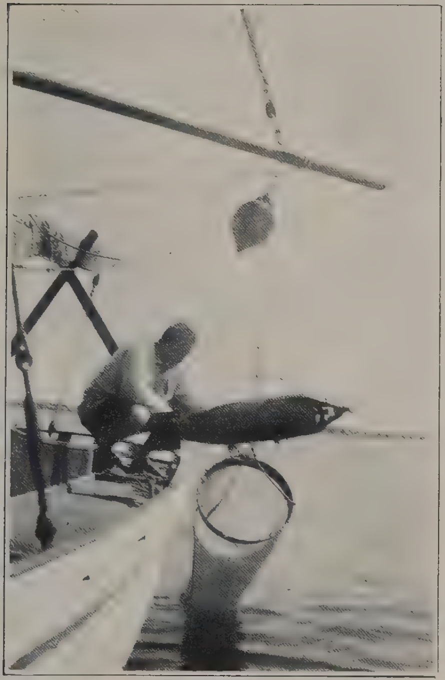

Photo H. C. Vidgen.] FIG. 1.

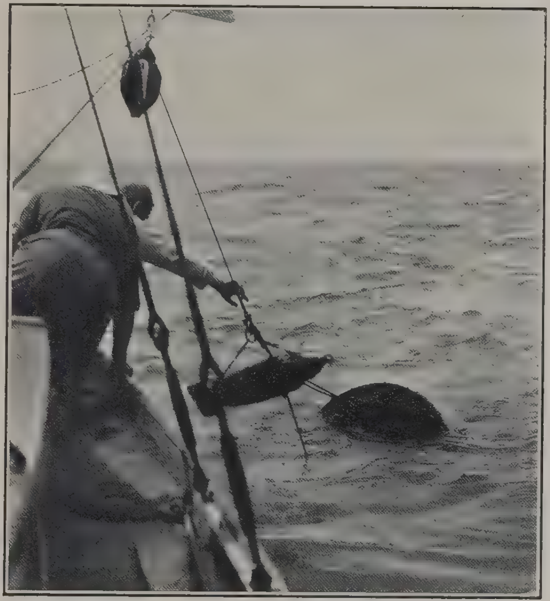

Photo A. C. Wishart.] FIG. 2.

Photo T. C. Roughley.] FIG. 3.

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INVESTIGATIONS

PHYSICAL AND CHEMICAL CONDITIONS IN THE SEA IN THE NEIGHBOURHOOD OF THE GREAT BARRIER REEF

BY

A. P. ORR,
Chemist at the Marine Station, Millport

WITH SEVEN TEXT-FIGURES

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INTRODUCTION.

The aim of the work described in the present report has already been referred to (Russell and Orr, Vol. II, No. 1), and in the same paper charts are given showing the position of the hydrographic stations. These charts should be used in conjunction with the present report. The seasonal observations were made at a position three miles east of Low Isles and are recorded in Table I. In addition several series of observations were made both inside and outside the Barrier Reef Lagoon to find the degree of uniformity of the area, and to record the changes in the deeper water beyond the Barrier Reef. The results are summarized in Tables II and III. They may conveniently be described under three headings: (A) The seasonal variations at the position three miles east of Low Isles; (B) conditions elsewhere in the Barrier Reef lagoon; and (C) conditions close to and beyond the Barrier Reef.

Throughout the work considerable help was given, particularly in the collection of samples, by members of the boat party and others, to whom I am much indebted. In addition, the meteorological records were taken by various members of the expedition: temperatures by Mrs. Stephenson and Messrs. Spender, Stephenson and Tandy; sunshine by Mrs. Yonge; wind force readings by Mr. A. G. Nicholls; rainfall by the lighthouse keepers. All of them I wish to thank.

The work was done during the tenure of a Carnegie Research Fellowship, and I have to thank the Trustees for their assistance.

METHODS.

Observations were made on as many of the physical and chemical conditions as time permitted, and as were thought to be of value more especially in relation to the biological part of the work to be recorded in later papers in this volume. Temperature, salinity, oxygen content, hydrogen ion concentration, dissolved phosphate, nitrate and silicate were estimated. In addition, the turbidity of the water was recorded. The methods adopted were those which have been found suitable for similar work in temperate waters.

Water samples were collected with the Pettersson-Nansen insulating water-bottle (Knudsen, 1923) at intervals of 5 or 10 metres except in the case of stations over 50 metres in depth. In shallow positions, the deepest sample was usually taken a few metres off the bottom to avoid possible contamination. The surface sample was usually within half a metre of the surface except in rough weather, when, to avoid errors caused by the bottle leaving the water with the rolling of the ship, the samples may have been slightly deeper.

The temperature was read immediately after taking the sample on the standard centigrade thermometer enclosed in the bottle, and except in the case of samples from 400 metres or deeper is correct to 0·02° C. Comments on the temperature of samples from deeper water appear elsewhere in the text.

Salinities were determined by the chloride titration method, using as standard sea-water provided by the Conseil Permanent International pour l'Exploration de la Mer. The salinities and densities were calculated from Knudsen's Hydrographical Tables (1901).

Dissolved oxygen was determined by Winkler's method, and the percentage saturation calculated from the table by Fox (1907), given also in Harvey (1928*b*). Oxygen determinations were always made as soon as possible after collection of the samples, the initial precipitation being generally carried out within two or three hours of collection. As, in most cases, there was but little difference in temperature between the water and the air, the error caused by the delay must be very small. On a small boat in rough weather, sufficient care in adding the reagents could not readily be taken.

The hydrogen-ion concentration was estimated by McClendon's colorimetric method (1917); the dyes normally used were cresol red and thymol blue, but the latter was necessary only in a few cases. The buffer tubes did not keep so well in a tropical climate as in a temperate; fresh buffer tubes had to be made on several occasions. When a fresh set was made these were compared with the previous set, and on some occasions a slight correction had to be applied to some of the later readings made with the old set. The corrections required were too small to affect the seasonal observations appreciably.

Dissolved phosphate was estimated by Atkins's modification (1923*a*) of Denigès' method (1920, 1921). This method is sensitive to arsenates as well as phosphates (Atkins and Wilson, 1927). Since the quantity of phosphate was invariably very small, except in deep water, no high degree of accuracy can be claimed for the results, though traces of phosphate were almost always present. Phosphate analyses were almost always made within a day or two of taking the samples.

Dissolved silicates were determined by Atkins's modification (1923*b*) of Diénert and Wandenbulcke's method (1923). The correction applied by King and Lucas (1928) to the picric acid standard has been used, but no correction made for salt error.

Samples for nitrate determination were preserved and analysed by Harvey's method (1926, 1928*a*) on the return of the expedition to Great Britain. They were stored in dark glass bottles holding about 200 c.c. All the samples of sulphuric acid taken by the expedition to Low Isles were found to be contaminated in varying degrees with oxides of nitrogen, and since nitrates were generally present only in very small quantities, even approximate analyses could not be made. Estimations of the dissolved organic matter were made by Ruppin's method (1904) on a few occasions.

The excess base was determined by McClendon's method (1917), and these, with calcium estimations, will be described elsewhere in the reports.

The turbidity of the sea-water was measured by the Secchi disc. For the normally slightly turbid water, the disc of 20 cm. diameter was quite suitable, but for the very clear water which may occur beyond the Barrier it is too small, and in these places the depth at which it disappeared may easily have been under-estimated.

A. SEASONAL VARIATIONS THREE MILES EAST OF LOW ISLES.

This position was chosen for a study of the seasonal variations because it was considered to be representative of the Barrier Reef Lagoon as a whole, and was at the same time easily reached from Low Isles. It was far enough removed from reefs to be free from local changes due to them, such as are described in the report following this. While the depth to north and south is uniform, or nearly so (about 33 metres), there is a gentle slope towards the land on the west and a slight deepening till the Barrier Reefs are reached on the east. There are, however, numerous obstructions, the most important of which, from the hydrographic point of view, are to the south and east, in the form of more or less submerged reefs. These will have some effect, in conjunction with wind currents, in mixing the sea-water in the lagoon.

Currents.

The S.E. trade wind causes a north-going current which, according to the 'Australia Pilot' (1928), varies in strength from 1 to 2½ knots. During the summer months (November to January) this wind is only spasmodic and may be replaced by a wind from a northerly direction (see Table IV and Text-fig. 2), causing for a short time a south-going current; but the S.E. wind has the predominating influence. The effect of the north-going current is shown clearly by the horse-shoe shape of the reefs lying in its path (Spender, 1930) and again by the north-pointing sand-spits on the continental islands (Steers, 1929). During the normal S.E. winds the tidal stream affects only the speed of the north-going current. No measurements of the current were made at the three-mile station, nor was it safe to judge from the rate of drift of the ship, since with her shallow draught the effect of the wind on the non-submerged parts must have been relatively great. Drift-bottle experiments were clearly inadvisable, considering the sparse population to the north. From the temperature and salinity observations, it is safe to conclude that the north-going current does not merely affect the surface layers, but extends to the bottom (32 metres). The observations made by the "Siboga" Expedition (Tydeman, 1903) on the monsoon currents in the East Indian Archipelago showed that there wind and tide currents extended to about 100 metres.

It is obvious, then, that the observations at the position three miles east of Low Isles are peculiar to the Barrier Reef Lagoon, and it cannot be assumed that the same conditions hold in the open sea beyond. The differences will be caused chiefly by the very considerable differences in depth inside and outside the Barrier, the north-going current in the lagoon and the obstructing effects of the numerous reefs.

Temperature.

The seasonal changes in temperature are shown in Table I and Text-figs. 1 and 2. The maximum temperature recorded was at the surface in summer (29·88° C. on 18th February, 1929), and the minimum (21·24° C. on 17th July, 1929) at 28 metres in winter. The annual range is thus about 8·6° C. This is somewhat larger than the annual range in comparable areas in temperate latitudes. The actual maximum and minimum may be slightly different from these recorded, for no observations were made of the diurnal range at the station. Samples were collected on most occasions between 8 a.m. and noon. During the period of trade winds the diurnal fluctuation was probably very small, but in the calms of summer it may have been considerable. In no case did the temperature exceed or fall below that which corals can survive (Mayer, 1918; see also p. 62).

The relation of the average temperature of the sea from top to bottom to the maximum and minimum air temperature is shown in Text-fig. 2. The temperature of the sea is dependent on air temperature, and lies on a curve between the daily maximum and miminum temperature of the air. In the same figure is shown the air temperature taken at 9 a.m. daily. This curve will approach the average daily temperature.

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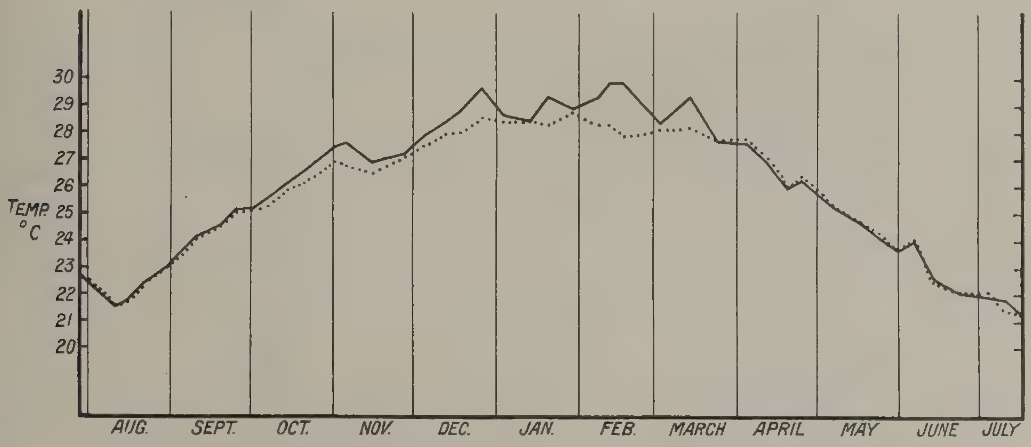
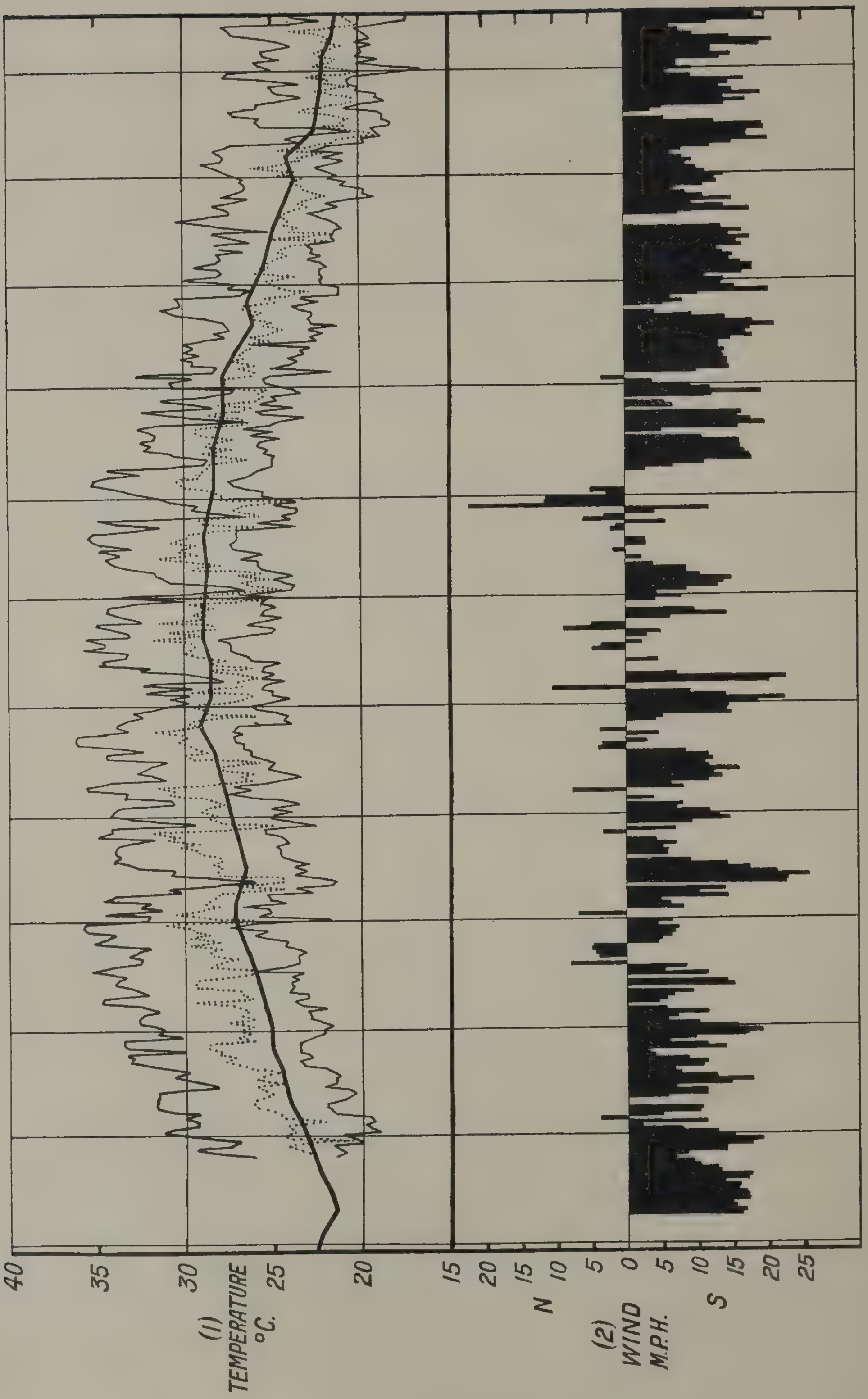
While warming is in progress, the curve for air temperature lies chiefly above the curve for average sea temperature. The sea, when at its warmest, is at almost the same temperature as the air, and while the sea is cooling, the air temperature is slightly lower. The lag of sea temperature behind air temperature is small in the spring, when warming begins, and is still less marked in autumn, when cooling begins. Irregularities in average sea temperature reflect short spells of warmer or colder weather. A greater lag of sea temperature behind air temperature would have been expected on account of the difference between the specific heat of the sea-water and that of the air. In addition, it must be remembered that the sea temperature will be affected to some extent by the air temperatures in the places where the sea-water has been before, *i. e.* for the major part of the year further to the south.

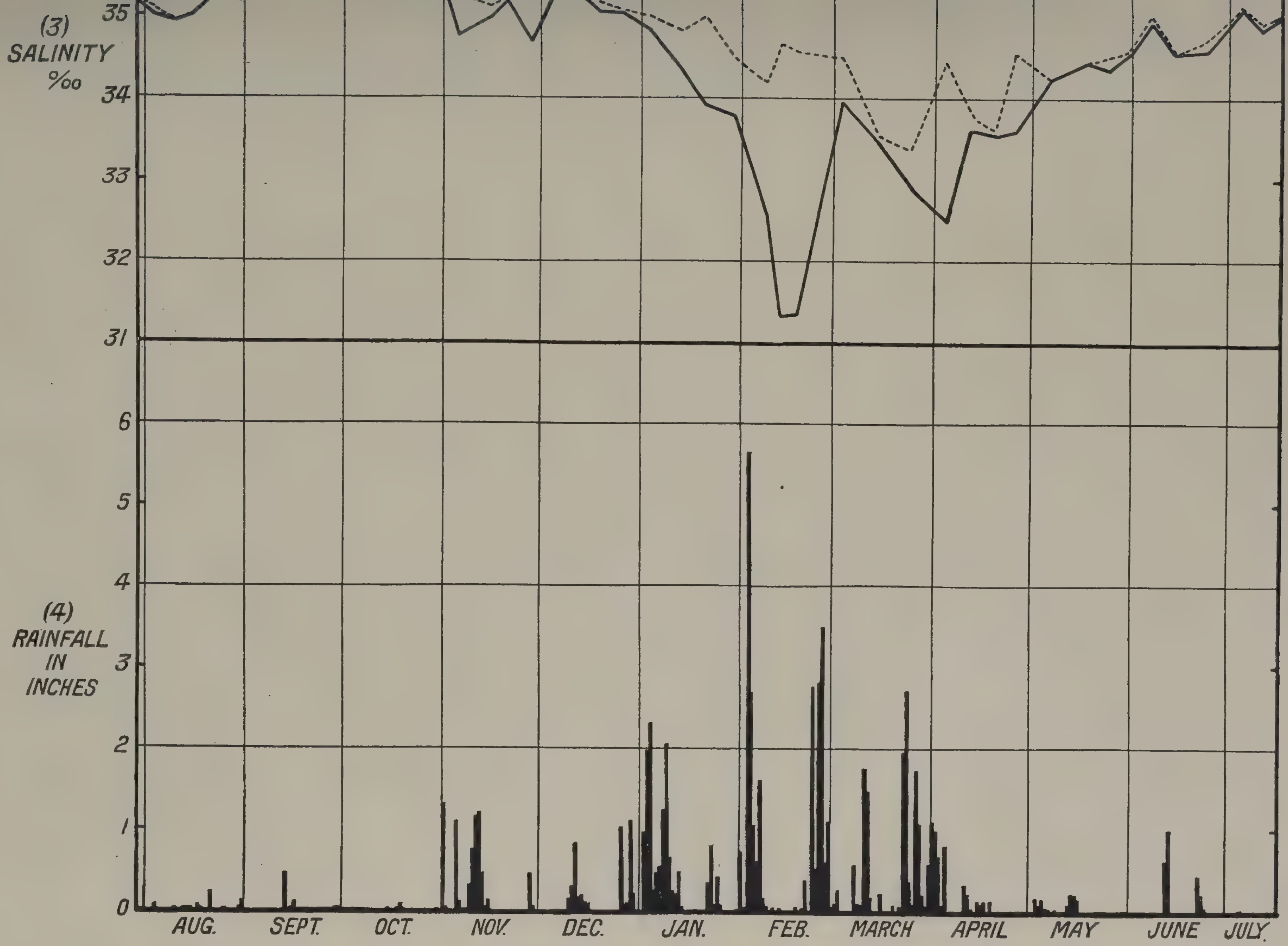
From wet- and dry-bulb thermometer readings (Table IV) it can be shown that a certain amount of evaporation is going on all the year, but the difference in aqueous vapour pressure between the sea and the air shows no important seasonal variation. In temperate waters, on the other hand, it has been shown (Harvey, 1925) that cooling of the sea is related to seasonal changes in evaporation.



TEXT-FIG. 1.—Temperature variations 3 miles E. of Low Isles. ——— surface, ... 28 metres.

The vertical temperature gradient (Text-fig. 1) is never great, and is only important for a short period in summer. During the major part of the year, enough turbulence is caused by the S.E. wind to mix the water from top to bottom ; thus the radiation absorbed at and near the surface is rapidly distributed throughout the water. The difference in temperature between surface and bottom is for that time very rarely more than a few tenths of a degree and is frequently negligible. In August, when warming begins, the surface water is usually slightly warmer than the deeper water, since some time is required for complete mixing. During the summer two factors make possible a thermal layering of the water ; firstly, the wind force diminishes (Table IV and Text-fig. 2) and turbulence is thus reduced ; secondly, summer is the rainy season (Table IV and Text-fig. 2), and the fresher water, being lighter, tends to remain at the surface. Heating of this surface layer still further reduces its density, helping to make the sea more stable. The maximum


(1) TEMPERATURE °C.
40
35
30
25
20
15
(2) WIND M.P.H.
N
20
15
10
5
0
5
10
15
20
25
S



Text-fig. 2.—Seasonal variations 3 miles E. of Low Isles. (1) Temperature: ——— average sea temperature, ——— maximum and minimum air temperature, ... air temperature at 9 a.m. (2) Wind force: average m.p.h. during 24 hours. (3) Salinity: ——— surface, - - - - - - - 28 metres. (4) Rainfall in inches.

temperature difference between bottom (28 metres) and surface was 2° on 18th February, 1929, the same date as that of the highest surface temperature. This reduction of density with warming at the surface is not carried far enough to overcome to any great extent the turbulence caused by winds, and a continued rise in the temperature of the deeper layers still goes on. In comparable areas in temperate latitudes, stabilization by the formation of light surface layers is much more marked and is of considerable biological importance. After the rainy season with its infrequent winds, cooling begins. Heat is lost by radiation and evaporation, so that in contradistinction to the spring (August to October), when the surface temperature exceeds the bottom temperature slightly, the surface temperature in this case is slightly lower than that of the deeper waters. These temperature differences are, however, very small, particularly when we compare them with the changes which occur in temperate latitudes.

Though temperature measurements were made at a series of depths on each occasion the station was worked, these are not shown in Text-fig. 1. They present no unexpected features, and, except for a short period during the autumnal cooling, have values almost always intermediate between the values obtained at the surface and at the bottom.

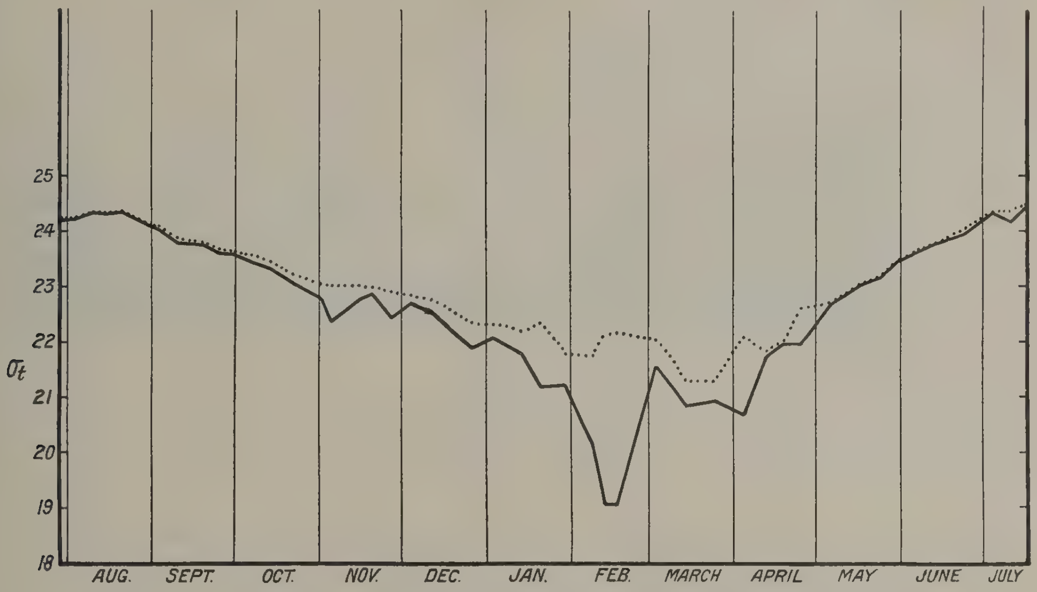
SALINITY.

The seasonal changes in salinity are given in Table I and Text-fig. 2. The maximum salinity found (35·47°/$_{\circ\circ}$ at 15 metres on 15th October) is a little lower than would be expected for this latitude (16° 24′ S.), but the proximity of the coast and the considerable land drainage offer a sufficient explanation. The salinity throughout the year is controlled chiefly by the rainfall (see Table IV and Text-fig. 2). During the dry months the salinity is high, and since these months are characterized by the S.E. trade wind, which is powerful enough to mix the water from top to bottom, the salinity is the same from surface to bottom ; the salinity at the surface is rarely more than a few parts per thousand lower. A fall of rain in calm weather leads to a diminution in the salinity chiefly of the surface water (*e. g.* 6th November), but when the wind freshens again, this water of low salinity is distributed throughout the water mass, causing a slight decrease in salinity from top to bottom (*e. g.* 14th November). During the summer months the winds are less frequent and of diminished force ; at this time also there is a high rainfall. The surface waters are then very much reduced in salinity, and an abrupt change in the salinity curve corresponds with days of heavy rainfall ; but the degree of reduction of salinity in the deeper waters depends on the amount of wind. The reduction of salinity depends of course not only on the rain falling on the sea directly but also on land drainage. The actual watershed on the mainland is close to the coast, but the rainfall during these months is very heavy compared with that at Low Isles (72 in.). At Cairns, for example, a short distance to the south, the average rainfall is 90 in., while in that district over 150 in. a year have been recorded.

To avoid confusion the curves for salinity at 5, 10, 15 and 20 metres are not shown in Text-fig. 2. In all cases at these depths the salinity lay between or was the same as the surface or bottom samples.

The lowest salinity recorded was 31·32°/$_{\circ\circ}$ at the surface on 13th February, 1929. This value probably fluctuates considerably from year to year and may have been surpassed in the year under consideration. For example, on 28th February, 1929, the Daintree river was in flood, and the discoloration caused by the influx of this turbid fresh water was plainly visible at Low Isles. Unfortunately work was going on elsewhere at this time and no records of salinity changes could be obtained. The value recorded above is not sufficiently low to be harmful to coral growth according to Mayer (1918 ; see also succeeding report), but a sudden change such as that caused by the flood-water of a river can, according to Hedley (1925*a*), have a catastrophic effect on reefs in the vicinity.

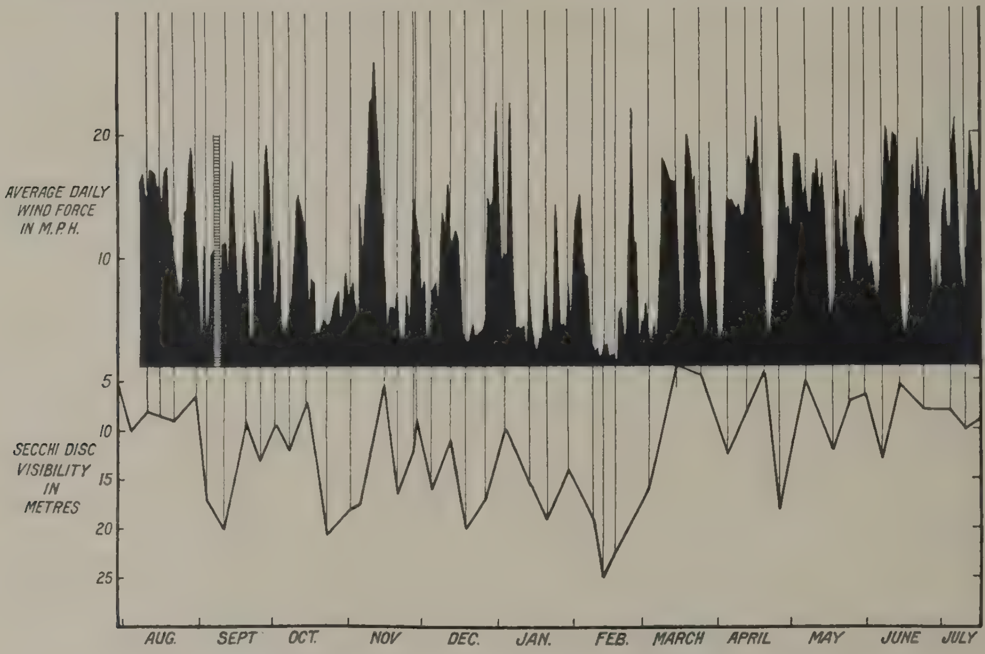
The most interesting feature of the salinity curves is the rapid return to approximately normal values after the heavy rainfall of summer. The comparatively fresh water is replaced rapidly by more saline water from outside the Barrier. That a considerable interchange goes on is evident from the irregularity of the salinity at the bottom (28 metres). For example, on 13th February there was a very considerable reduction of the surface salinity caused by a heavy rainfall in calm weather. In spite of this there was an abrupt *increase* in the salinity at the bottom (34·20 $^\circ/_{\circ\circ}$ to 34·68 $^\circ/_{\circ\circ}$). Again, on 5th April, in spite of a considerable drop in the salinity at the surface, there was an *increase* (33·38 $^\circ/_{\circ\circ}$ to 34·44 $^\circ/_{\circ\circ}$) at 28 metres. It is not likely that the coastal water being driven up from the south is more saline, for the rainfall is heavy all along this coast and the depth is not much greater to the south. On the other hand, there are tidal currents through the passes in the Barrier (*e. g.* Trinity Opening some 20 miles away) through which more saline water may come. To the south also, from which direction the current comes, the passes are very numerous. There is a rapid increase in depth from the shallow coastal water of the lagoon to oceanic depths beyond. The salinity increases with the decrease in rainfall, and during the driest part of the year (August to October) is constant, equal from top to bottom, and the same as it is in the surface waters beyond the Barrier (pp. 55–60).



TEXT-FIG. 3.—Variations in density 3 miles E. of Low Isles. $\left(\text{Density} = 1 + \frac{\sigma_t}{1000}\right)$.
—— surface, ... 28 metres.

DENSITY.

It is salinity rather than temperature which is the determining factor in the stability of the sea in the Barrier Reef lagoon. In Table I and Text-fig. 3 are shown the seasonal changes in density at the surface and at the bottom. They are very similar to the salinity changes shown in Text-fig 2. From May till September there is very little difference from surface to bottom, so that the sea is homogeneous. This is undoubtedly caused largely by wind. It is only during the rainy season when winds are less frequent that the difference between surface and bottom is important, and even then rapid changes in the density at the bottom take place when even a moderate wind blows. The rise in density at the bottom with the inflow of oceanic water is also noteworthy. The influence of this lack of stability on metabolism in the sea is described on pp. 61–63.



TEXT-FIG. 4.—Seasonal variations in wind force and turbidity. The vertical lines indicate the dates on which Secchi disc observations were made.

TURBIDITY.

The variations in turbidity at the weekly stations are shown in Table I and Text-fig. 4. The low average transparency (about 12 metres*) was unexpected, for it is a commonplace observation that coral seas are remarkably clear. Hitherto very few actual measurements have been made, the statements depending on the opinion of the observer only. Hedley (1925*b*) made a few measurements with a modified Secchi disc in the Barrier

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* Erroneously stated as 8 m. in Vol. I, No. 5.

Reef region, finding a maximum of 20 metres and a minimum of 5 metres in the lagoon; Davis (1928) noticed that rough weather caused turbidity inside the Barrier at Fiji as well as inside the Australian Barrier. More recently Verwey (1931) has made a study of the turbidity near the coral islands in the Bay of Batavia. His results also show a much greater turbidity than might have been expected in the neighbourhood of coral. He arrived at the following conclusions: (1) The quantity of silt is related to the depth of the water. (2) It takes some time after a stormy day or a windy period before the large quantity of silt has settled again. It might be expected from this that, at the station three miles east of Low Isles, the turbidity would be directly related to the wind. In the diagram (Text-fig. 4) it is shown that this relationship is close if we remember that it takes some time for the silt to settle after a storm. Since Secchi disc readings were only taken about once a week there is not a peak on the turbidity curve to correspond with every wind peak, but the peaks and valleys in the turbidity curve do correspond to stormy and calm periods. Successive readings were taken at the station three miles east of Low Isles on 28th and 29th November, 1928. On the first day the wind was light, but increasing while observations were being taken. The reading of the disc was 12 metres. By the next day, the reading had dropped to 9 metres. The maximum reading is not likely to have exceeded 27 metres, while the minimum is not likely to have been less than 3 metres. The recorded maximum and minimum were 22·5 and 4·5 metres respectively. The average value for the year was only about 12 metres, so that the average visibility is probably about the same as in the English Channel, where it is also about 12 metres (Poole and Atkins, 1928; Russell, 1928).

While this high degree of turbidity is characteristic of the water inside the Barrier in the neighbourhood of Low Isles and also further north (p. 54), it is not so common near the outer reefs or beyond the Barrier (pp. 55–60). This distribution gives us a clue to its cause, for near the outer reefs and beyond the Barrier the bottom is coral or coarse coral sand or the water is deep, whereas inside, the depth is only about 30 metres and the bottom is a fine grey silt.

Numerous analyses of the sand on Low Isles Reef flat are given by Marshall and Orr in Vol. I, No. 5, and these are similar to the sediments occurring near the outer Barrier Reefs and on other reef flats. The fine grey silt, however, is of very different composition. Mr. B. H. Barrett, of the Geology Department, University of Glasgow, in a personal communication gives the following analysis of the top 3 cm. of the sea bottom from the position three miles east of Low Isles:

Grade.	0–1 cm. %.	1–2 cm. %.	2–3 cm. %.
Clay (less than 0·01 mm. diam.)	34·16	29·8	38·29
Fine silt (less than 0·05 mm. diam.)	25·26	10·07	18·92
Coarse silt (less than 0·1 mm. diam.)	7·5	42·9	30·45
Fine sand (less than 0·25 mm. diam.)	2·08	0·74	0·67
Medium sand (greater than 0·25 mm.)	30·73	16·23	11·71

The fresh S.E. trade wind causes enough turbulence in the sea to stir up the clay and fine silt and so renders the water less clear. It is true that in the Anchorage at Low Isles during stormy weather the turbidity might be considerably greater than at the station three miles to the east, and this might lead one to suppose that the turbidity of the sea in the lagoon between the Barrier and the mainland was caused only by the disturbance of the shallow water near the islands. The results from the cruise to the north (p. 54), however, do not support this explanation. Though the relation between winds, waves and depth of disturbance in the sea is not fully understood, the data available (*e. g.* Johnson, 1919) give support to the above conclusions.

Other factors which may affect the turbidity are the flood waters of rivers and the plankton. On one occasion (pp. 44–45) during the rainy season, the flood waters of the Daintree river caused an increase of turbidity readily visible to the eye. No Secchi disc readings were taken, however, and since during the rainy season there are longer calm periods (*cf.* wind force diagram, Text-fig. 2), this sediment would settle rapidly, and not affect the Secchi disc reading at the station three miles east of Low Isles taken some days later. The plankton was nearly always too small in quantity to affect the Secchi disc reading appreciably, though it may do so in temperate waters during a diatom increase (Marshall and Orr, 1930). On some occasions there was a large amount of *Trichodesmium* at or near the surface though it was very local in abundance. On one occasion when the reading of the disc was 10 metres at the station three miles east of Low Isles, it was as little as 7½ metres about a mile nearer Low Isles in an area where *Trichodesmium* was abundant. The occurrence of *Trichodesmium* was too infrequent to affect the curve appreciably.

Biologically the increase of turbidity is of importance since it reduces the depth to which photosynthesis can go on. At the same time the sediment may have other effects on reef-building corals. This latter aspect has been dealt with elsewhere in the reports (Marshall and Orr, Vol. I, No. 5.)

ORGANIC MATTER.

There is as yet no very satisfactory method for the estimation of organic matter in sea-water. The presence of a large quantity of salts makes the direct method of estimation subject to large errors, so that it is usual to estimate it by oxidizing in alkaline solution with permanganate. Unfortunately only a part of the organic matter is oxidized by this, and the quantity oxidized depends on the nature of the organic substances present. For this reason only a few estimations were made in the sea-water during the course of the year. The results which are given in Table I are of the same order of size as those obtained by Atkins in the English Channel (1923*c*), and the differences at different times of the year are small. The fact that the sea bottom three miles east of Low Isles contains an appreciable quantity of organic matter (Marshall and Orr, Vol. I, No. 5) leads to the expectation that the organic matter will be associated with the degree of turbidity of the sea-water. This was tested on two occasions—the 16th and 21st November, 1928. On the former date the Secchi disc reading was 5·5 metres and the organic matter averaged 0·64 mg./l.; on the latter date the Secchi disc reading was 16·5 metres and the organic matter averaged 0·43 mg./l. As other analyses show, however, the organic matter content cannot always be taken as an indication of the degree of turbidity of the water.

OXYGEN.

Normally the dissolved oxygen in the shallower parts of the sea is in equilibrium with the air, or nearly so. In order to correct for the changes in oxygen content caused by variations in temperature and salinity, it is convenient to express the oxygen, not as cubic centimetres per litre, but as percentage saturation. In temperate waters, where there is a marked seasonal change in the plankton, the oxygen saturation of the well-illuminated layers is over 100% when plant life is rich; conversely, the deeper layers show a fall in oxygen saturation owing to consumption by animals. In the Barrier Reef lagoon, however, the seasonal changes were negligible. The sea at the station three miles east of Low Isles was, as a rule, slightly under-saturated with respect to oxygen, the values lying generally between 90 and 100% (Table I and Text-fig. 5). Only on one occasion was the surface supersaturated (2nd November), and only for a short period during summer did the deeper water fall below 90% saturation. The cause of this general under-saturation may be partly the respiration of animals, but is probably caused chiefly by the oxidation of dead organic debris on the sea bottom and in the water itself.

A large quantity of organic debris is carried off the reef flats and deposited in the sea, and vegetable detritus is carried in by rivers during floods. The sediment being carried off Low Isles reef was collected and analysed (Marshall and Orr, Vol. I, No. 5); it was found to contain from 3–6% organic matter. Three miles east of Low Isles the mud on the sea bottom was found to contain 2·2% organic matter. This silt, if allowed to stand in a jar filled with sea-water in the laboratory, removes the oxygen from it rapidly, and eventually hydrogen sulphide is formed. On the sea bottom the mud is light grey in colour, but after standing under water in the laboratory for some days it turns black owing to sulphide formation. It is obvious, then, that in the sea its gradual oxidation will tend to reduce the oxygen saturation value. During windy weather the finer material from the sea bottom is undoubtedly distributed through the water mass (see p. 47), where it brings about a reduction in the oxygen content.

It was frequently observed that samples of sea-water brought in for laboratory purposes showed a reduction in their oxygen content with time much greater than is commonly met with in sea-water in temperate regions. This fall in the oxygen content persisted even after the water had been freed from most of the suspended matter by filtration through a sintered glass filter. For example, on one occasion a sample was collected in a thoroughly cleaned Winchester and a number of clean oxygen bottles filled with the unfiltered water. At the end of 24 hours the fall in oxygen content was 0·13 c.c. per litre, and after 3 days, 0·41 c.c. per litre. Of 17 different samples filtered first through filter-paper and then through a Jena sintered glass filter and set up in the same way for 24 hours, there was an average reduction in oxygen content of 0·25 c.c. per litre. All samples were collected in the anchorage and kept in the dark at air temperature. A similar phenomenon has been described by Gran and Ruud (1926) for temperate regions. As has been shown (p. 48 and Table I), the organic matter in sea-water as measured by permanganate is, on the whole, somewhat less than in temperate waters, but it must be remembered that this method is rather unsatisfactory because of the incompleteness of the oxidation. It is also certain that the utilization of the oxygen in the sea-water is considerably increased by the higher temperatures prevailing in the tropics.

Except for the calmer period, when there was a certain degree of stability, there was no appreciable difference in the oxygen content at the surface and at the bottom. During this calm period, however, there was a definite though slight fall in the oxygen content of the deeper water, the minimum value reached being 87% saturation when at the surface it was 96%. During the remainder of the year there were slight differences affecting all depths, but changes caused by plant and animal life were either too small, or were masked by the mixing of the layers.

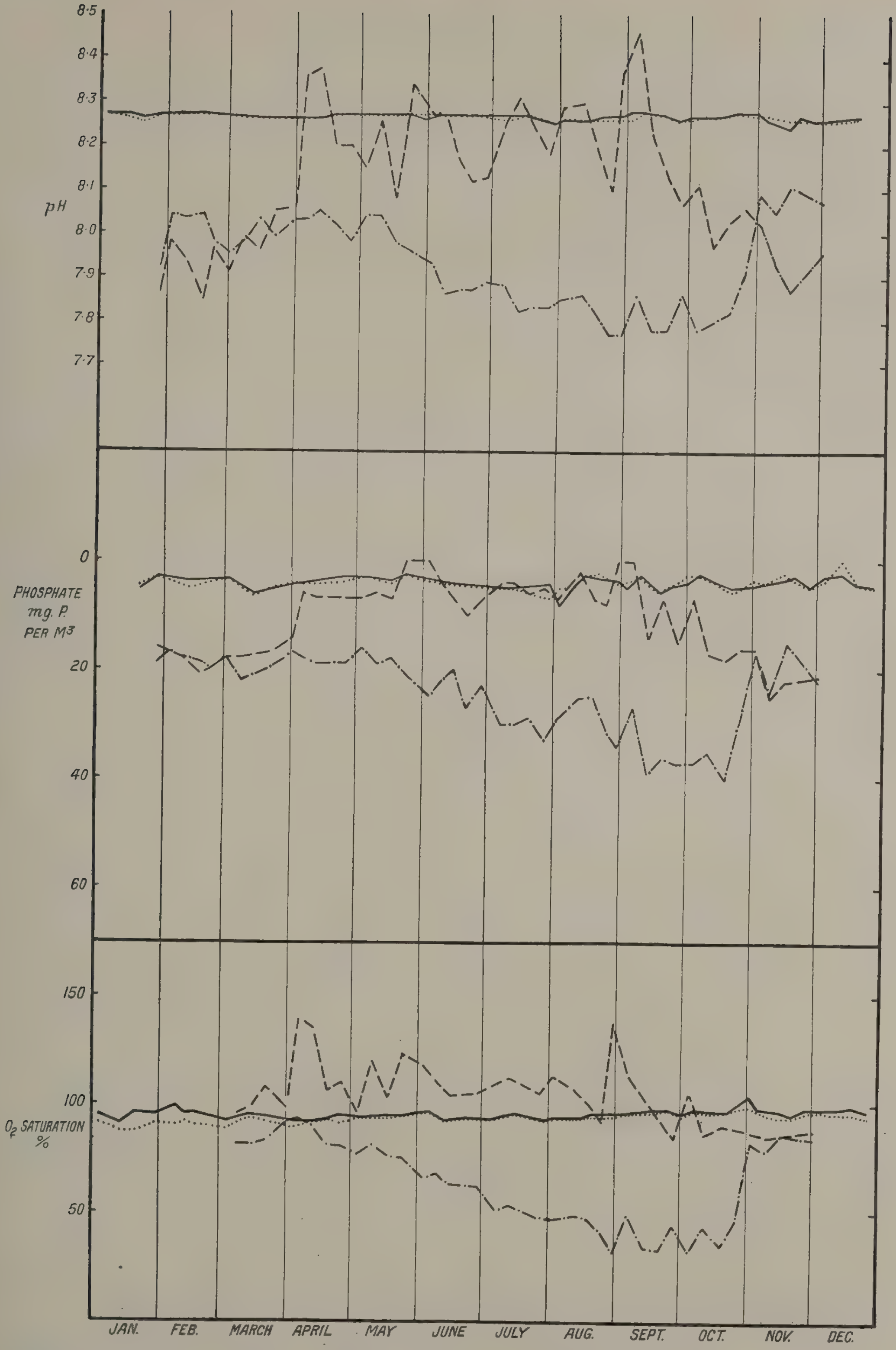
It is shown in the next paper that there are very large fluctuations in the oxygen content of the water on reef flats and immediately above growing coral. The production of oxygen through the day is always in excess of the utilization by the corals and other animal life ; during the night there is a large oxygen consumption. The resultant effect over a period of 24 hours is small. An important fraction of the area between the outer edge of the Barrier and the mainland is covered by reefs, but it has no appreciable effect on the oxygen content of the lagoon. The most probable explanation of this is that the *volume* of water which is supersaturated during the day or under-saturated during the night (down to a depth of a few metres at most) is a negligible fraction of the total volume of the lagoon. The supersaturated or under-saturated water does not remain on the surface, but is distributed by wind action throughout the water column. In the close vicinity of a reef to leeward the oxygen content may be a little higher during the day, but at a distance of a few miles there is no longer a recognizable effect. From a study of the conditions on a reef and in the neighbouring sea, it is clear that the frequently expressed opinion that corals on the windward edge of a reef grow more vigorously because of the higher oxygen content of the water is no longer tenable. The fluctuations in the oxygen content of the sea in the Barrier Reef lagoon can have no important effect on the life in it.

Phosphate and Nitrate.

Phosphate and nitrate are essential foods for plants, and though in the sea they are generally present in extremely small quantities, the productivity of the sea is often dependent on the presence or absence of these salts. With respect to phosphate and nitrate, the Barrier Reef lagoon showed no seasonal character (Table I). Both were present in very small quantities throughout the year. The phosphate content (Text-fig. 5) was rarely as much as 8 mg. P. per cubic metre, but on the other hand, it fell below the limits of analysis only on one or two occasions. The average quantity of phosphate was generally about 5 mg. P. per cubic metre. Photosynthesis would have been expected to result in the removal of this small quantity of phosphate from the upper well-illuminated layers, and regeneration by decomposition and animal metabolism to produce a bottom layer rich in phosphate. The constant mixing of the sea, however, did not allow of an accumulation of regenerated phosphate in the deeper layers, and at the same time prevented its complete removal from the photosynthetic zone. As a result plant growth was possible throughout the year, though limited in quantity. Even during the short calm spells in summer, when mixing was incomplete, the phosphate value did not rise in deep water. On only one occasion was a high value obtained in the deepest sample (14 mg. P. per cubic metre at 28 metres on 11th November), but as it did not persist and was not reflected in any of the samples from lesser depths, it was considered most probable that contamination had taken place.

The large influx of fresh water from rivers during the rainy season might have been expected to result in an important addition of phosphate. The Daintree River, however, when examined during the dry season had only traces of phosphate. There was, moreover, no increase in the values for the sea during the periods of low salinity.

It might have been expected also that in seas so rich in coral growth an important quantity of phosphate as well as of soluble salts of nitrogen would have resulted from the excretions of the corals on the numerous reefs. The facts, however, are quite to the



TEXT-FIG. 5.—Seasonal variations 3 miles E. of Low Isles compared with variations in temperate waters (Loch Striven). (1) pH value. (2) Phosphorus. (3) O_2 saturation. ——— Low Isles surface. .... Low Isles, 28 metres. — — — — Loch Striven, surface. —·—·—·— Loch Striven, c. 60 metres.

contrary. In the next paper it is shown that in the coral pools on the reef flat of Low Isles there was no increase in the quantity of phosphate present, and that the quantity in these reef pools at low tide during the day or the night is negligible. This result has also been confirmed by Yonge and Nicholls (Vol. I, No. 6), who found that reef-building corals containing zooxanthellae not only do not excrete phosphate into sea-water, but actually remove it. Thus the very small quantity of phosphate actually present in the sea in the Barrier Reef lagoon is not all available for the growth of the phytoplankton, but is being removed by the zooxanthellae in the corals themselves.

The dissolved phosphates in the lagoon are probably derived chiefly from the bacterial decomposition of the organic matter on the sea bottom, as well as from the detritus swept in from coral reefs and from rivers in flood. It has already been shown (p. 49) that the mud on the sea bottom is capable of removing a considerable amount of oxygen from sea-water, and from observations on the phosphate content of the sand on reef flats, it may justly be inferred that a considerable amount of soluble phosphate is liberated. At a short distance below the surface over almost the whole of Low Isles reef flat, the sand is black, while above this and on the surface it is greyish yellow in colour. The water in the black sand is deficient in oxygen and is rich in soluble phosphate. Samples of the surface sand taken near the Anchorage contained as much as 3 mg. soluble P. per kg. The mud from the mangrove swamp contained nearly 90 mg. soluble P. per kg. The coarse sand found on spits, which are disturbed by wave action at each high tide, contained only a trace. During the major part of the year the wind force is great enough to keep the water in the lagoon mixed from top to bottom. At the same time there is a disturbance of the fine sediment on the sea bottom. Evidence of this is provided by Secchi disc readings, which run parallel to readings for wind force. The fine sediment with its soluble phosphate is thus distributed throughout the water.

Only a small number of estimations of nitrates were made in surface and bottom samples, since the analyses could not be made till the return of the expedition. The results were low, and may have been affected by the long period of storage of the samples. Either or both phosphate or nitrate may be limiting for plant growth at times but neither is present in sufficient quantity to allow of an abundant growth, such as is experienced at certain seasons in temperate and polar regions.

Silicates.

Silicates were estimated occasionally, the sample being first concentrated by evaporation after filtration, since values were comparatively low. As in temperate waters, the quantity of silicate was invariably high compared with other nutrient salts, and it is improbable that the smallness of the quantity of soluble silicate limits plant growth at any time of the year. In addition the Daintree River, which flows into the lagoon a little to the north of Low Isles, though poor in soluble phosphate, was rich in soluble silicate. The maximum value for silicates was just over 100 mg. per cubic metre and the lowest about 40.

Hydrogen Ion Concentration.

Measurements of the hydrogen ion concentration (Table I and Text-fig. 5) were made throughout the year, and, as might be expected from the results of oxygen saturation determinations and from phosphates, they show little change. The absence of any important seasonal cycle in plant growth resulted in a uniformity in the carbon dioxide equilibrium. The average pH value was 8·26 and the maximum change was less than 0·1. Similar values were found by McClendon (1917) in the Tortugas. In the next report the changes on the reef flat of Low Isles are recorded. The diurnal change in pH value there is very large, and similar changes undoubtedly occur on all coral reef flats. The changes, however, are in too small a volume of water to have any appreciable effect on the surrounding sea. It was rather surprising that even when *Trichodesmium* was abundant at the surface in the sea, there were no unusual values for the hydrogen ion concentration.

B. CONDITIONS ELSEWHERE IN THE BARRIER REEF LAGOON.

The conditions already described for the position three miles east of Low Isles hold for a considerable distance to the north and to the south of this position during the period of the S.E. trade wind. Any differences which exist, however, are likely to be accentuated during the wet season (January to March), with its frequent calm spells and occasional periods of northerly winds. Two short cruises were made to the north during this period (25th February to 1st March, and 17th March) to find whether the conditions differed appreciably from those near Low Isles. In addition, a line of stations was worked across the lagoon in winter from the mainland (mouth of the Daintree River) to the Barrier Reef (Satellite Reef) to find whether the proximity of the land or of the reefs had any appreciable effect. The results from Trinity Opening to the south are also included. They are given in Table II, and the positions shown in Charts I and II in the preceding report in this volume by Russell and Orr.

Stations North of Low Isles.

The first cruise to the north was made immediately after a small cyclone had crossed the coast between Low Isles and Cooktown. During the period of the cruise the weather was very uncertain, with a good deal of rain and wind. The wind was from the north, a direction from which it rarely blows except during summer. Stations were worked at S. Cape Bedford, 69 miles north of Low Isles; south of Lizard Island, 102 miles north of Low Isles; in Cook's Passage, about 10 miles north-east of Lizard Island; and 1 mile south of Two Isles, which is 83 miles north of Low Isles. A little more than a fortnight later a station was worked in Papuan Pass, which is 40 miles north of Low Isles, but this time in calm clear weather.

Temperature.—At S. Cape Bedford and south of Two Isles temperature conditions were very similar to those three miles east of Low Isles at the same period. There was a slight rise in temperature from bottom to surface, and though less than 1° C. it was more than was expected considering the strong north wind which was blowing. A short distance to the north, however, south of Lizard Island, though the gradient in temperature was similar, the values were almost a whole degree lower. Whether this is because of its proximity to Cook's Passage, in which temperature conditions were similar and which communicates directly with the open Pacific, is not clear, since such a conclusion is not borne out by the salinity observations. In Papuan Pass, which is similar geographically to Cook's Passage, the temperatures were also slightly lower than east of Low Isles for a corresponding date.

Data on temperature, additional to those recorded in Table II, have been made available through the kindness of the Commonwealth Navigation and Lighthouse Service of Australia. These are surface temperatures, and have been taken for several years by the officers of the S.S. "Cape Leeuwin" and S.S. "Cape York" during periodic cruises along the whole of the Barrier Reef lagoon. While too few in number to enable the seasonal changes in temperature at different parts of the Barrier Reef lagoon to be deduced, they are interesting in that they show approximately the limits of the surface temperature range in the area. The highest temperature recorded (28·9° C. at Low Isles and at Thursday Island) is no higher than was obtained at Low Isles by the expedition, while the lowest recorded to the south (17·8° C. at Breaksea Spit, 24° 38′ S., 152° 47′ E., the southernmost limit of the reefs) is lower than was obtained by the expedition at the position three miles east of Low Isles, and is interesting, since it is lower than the lethal limit for corals given by Mayer (1918). There is, however, a surprisingly small difference of temperature with latitude. The maximum difference recorded in the course of one month between Breaksea Spit and Cape York (a difference in latitude of about 14°) was less than 7° C., while the minimum difference was less than 1° C.

SALINITY.—At S. Cape Bedford and in Cook's Passage the salinity was practically the same as it was three miles east of Low Isles at the same date. South of Lizard Island, however, the salinity was slightly higher. There was only a small gradient from surface to bottom. The anomalous conditions in this area are probably to be explained rather by the unusual weather at the time (north wind and heavy rainfall) than by any peculiarity of the area.

In Cook's Passage at the time of the observations there was a strong tidal current running, and the data obtained are probably dependent to some extent on the state of the tide. At Papuan Pass the salinity was slightly higher than at the position east of Low Isles, and this, again, is probably related to its proximity to the open ocean and the calm, settled weather at the time.

TURBIDITY.—The turbidity observations showed a relation both to position and to the weather. At S. Cape Bedford the turbidity was considerable, while south of Lizard Island and in Cook's Passage the water was clearer. In these last two positions the bottom consists of coarse sand or coral, while at the first it is muddy. The turbidity is probably dependent to some extent on the nature of the bottom. The greater clearness of the sea in the neighbourhood of Lizard Island, especially to the east, has been noticed by others (*cf.* 'Australia Pilot', 1928, IV, p. 191), and is probably normal. In Papuan Pass the transparency was also considerable.

OTHER CONDITIONS.—Apart from the abnormal station S. of Lizard Island, which showed a slightly lower oxygen saturation parallel to the peculiarities in temperature and salinity, there was no significant difference in other conditions from those east of Low Isles. Plant nutrient salts were present in extremely small quantities, and the pH value was normal at about 8·26.

TRINITY OPENING.

Stations were worked in Trinity Opening on three occasions between August and November, 1928. From the hydrographic point of view these were very little different from the position three miles east of Low Isles at similar dates. As might be expected from the greater depth of the stations, there was a slightly greater range in temperature from surface to bottom, while the oxygen saturation was slightly lower in deep water on all three occasions and slightly higher at the surface on one occasion. In spite of the depth being about 50 metres compared with 32 metres at the position three miles east of Low Isles, there was no definite discontinuity layer. The water was, however, considerably clearer than at the weekly station.

Cross Section.

Four stations were worked in a line from the mouth of the Daintree River to Satellite Reef during the dry season. One of these (H7) was at the usual position three miles east of Low Isles and was worked four days earlier than the other three ; the difference from the others is accounted for by this difference in time. There was almost complete uniformity of conditions across the lagoon. Temperature was slightly lower near the land, but the difference was so small that it is possible that the difference in the time of day is sufficient to account for it. Salinity was only slightly lower near the river mouth and uniform elsewhere. Other conditions were normal.

c. CONDITIONS BEYOND THE BARRIER.

It was possible to examine the conditions outside the Barrier on only four occasions—twice in the vicinity of Trinity Opening, once beyond Papuan Pass, which lies about 40 miles to the north, and once beyond Cook's Passage, N.E. of Lizard Island. The positions of these stations are shown in the charts in the preceding report by Russell and Orr. The positions are all within a few miles of the Barrier, and are not necessarily characteristic of the open ocean to seaward. According to the ' Australia Pilot ' (1928), a south-going current runs close to the Barrier on its seaward side. Outside Cook's Passage, however, the direction of this current is reversed, *i. e.* it runs there in a northerly direction. The existence of the south-going current was obvious in calm weather when the hydrographical observations were made outside Trinity Opening and Papuan Pass ; there was a slight southerly drift. Outside Cook's Passage, in spite of a fresh northerly wind, the drift was to the north. Some 20 to 30 miles beyond the Barrier the current is uncertain, but with strong S.E. winds a current up to about 1 knot sets with the wind.

It has already been mentioned that for the greater part of the year a fresh S.E. trade wind blows home on the Barrier. This will by itself alter the strength of the currents and possibly other conditions on the seaward edge of the Barrier. With the small boats at our disposal it was impossible to investigate the conditions in the normal S.E. weather, so that the findings may not be typical for the positions discussed ; in addition, the infrequency of the observations and the large area covered preclude any attempt at defining the seasonal variations outside the Barrier.

The results of the observations on the seaward edge of the Barrier are shown in Text-fig. 6 and Table III. Except at Trinity Opening, the descent to deep water from the Barrier edge is very steep, the depth reaching several hundred fathoms in less than a mile outside both Papuan Pass and Cook's Passage. At Trinity Opening the bottom shelves more gradually and resembles the region to the south. The steep seaward slope, characteristic of barrier reefs in general, extends northwards of Trinity Opening for several hundred miles. The difference in the character of the Barrier and the seaward slope to the south and to the north of Trinity Opening is described by Spender (1930).

Outside Trinity Opening.

The deep water outside Trinity Opening was examined in October and November, 1928 (Text-fig. 6 and Table III). The conditions from the surface to 50 metres were similar to those at the station in Trinity Opening at about the same time, there being minor differences in temperature and salinity; the sea outside was slightly warmer and somewhat more saline.

Between 50 and 100 metres there was a rapid fall in temperature, which continued to the greatest depth sampled (600 metres).* Salinity increased rapidly to 100 metres, and then decreased with increasing depth. The actual maximum for salinity probably occurs below 100 metres, and on one occasion (Station H. 22B) was obtained at 180 metres. Though the salinity falls continuously with depth below 100–200 metres, stability is maintained by the fall in temperature with depth (see density curve, Text-fig. 6). Between 50 and 100 metres there was also an abrupt fall in oxygen saturation, and below this it remained fairly constant at about 65% saturation. pH value fell rapidly to 200 metres, and then more gradually; phosphate content increased rapidly to 100 metres, and then more gradually to the greatest depth sampled.

The vertical section made here shows clearly that changes in the composition of the water due to biological activity are restricted to the upper 50 or 100 metres. At and above 50 metres plant food salts are present in very small quantities, and the gradient in temperature, salinity and oxygen saturation is negligible. The abrupt change in conditions with increasing depth (between 50 and 100 metres outside the Barrier) was never met with inside the Barrier, where presumably the water is too shallow. It marks the limit for vertical mixing of the water, and the depth at which it occurs is of considerable biological importance.

On Linden Bank (Table III), a coral bank about 35 metres in average depth, which lies to the N.E. of Trinity Opening, the conditions were very similar to those in the upper layers of the deep station to the east of it and to the station three miles east of Low Isles; there was no evidence of a disturbance in the water layers caused by the sudden depth changes. At the 100 fathoms line, however (Station H. 22B), there were differences from the deep station further east, which suggested a small disturbance of the layering close to the reef. At 100 metres, for example, the water was somewhat colder and more saline than at 100 metres at the deep station to the east. There was very little wind when the observations were made, and it is impossible to say whether the same picture would have been obtained during the period of the S.E. trade wind.

The possibility of a disturbance of the layering of the water on the outside of the Barrier is one of considerable biological importance. If the disturbance were sufficiently great, the water which normally lies between 50 and 100 metres, and which contains significant quantities of plant food salts, might be brought up into the better illuminated zone nearer the surface and so give rise to an increase in the phytoplankton. A more

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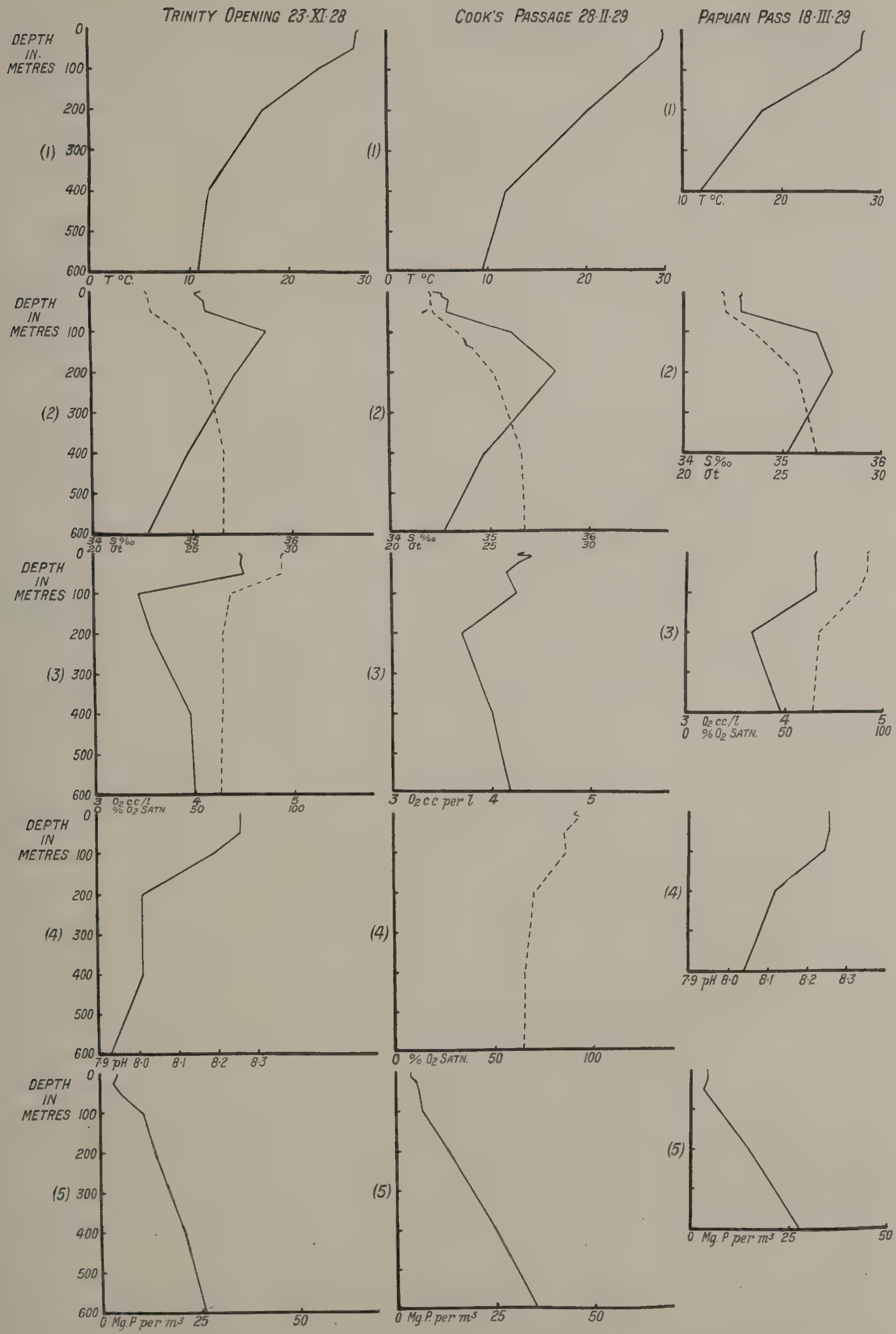
* It should be mentioned that the temperatures recorded for the deepest samples from outside Trinity Opening in October are not very reliable, because of the time which elapsed between taking the samples and reading the temperature. The delay in reading the temperatures was caused by the use of a hand winch for bringing the water-bottle to the surface. At all other deep stations, however, a power winch was used, and the time interval between closing the bottle and reading the temperature was considerably reduced. The error in temperature readings in these cases is very small.



TEXT-FIG. 6.—Conditions on the seaward edge of the Barrier Reef. (1) Temperature. (2) ——— salinity, - - - - - - - - density. (3) ——— O_2 c.c./l, - - - - - - - - O_2 saturation %. (4) pH. (5) Phosphate as mg. P./m^3.

marked disturbance of the layering than at Trinity Opening was found outside Papuan Pass (see below), and a similar but more striking upwelling occurs along the coast of California (Bigelow and Leslie, 1930 ; Moberg, 1928). In the last locality the upwelling brings deep water rich in plant nutrient salts into the actual surface layers, and causes there an abundant production of phytoplankton.

The observations beyond Trinity Opening were made near the beginning of the rainy season, and it was not till March, which is almost the last of the rainy months, that the deep water to the north could be examined. For this reason a strict comparison between the results from beyond Trinity Opening with those from the deep water to the north is not possible.

Outside Papuan Pass.

Outside Papuan Pass (see Text-fig. 6 and Table III), as beyond Trinity Opening, the water from the surface to 50 metres was almost homogeneous, and similar to that inside the Pass. The temperature was approximately the same as that three miles east of Low Isles at about the same date, but the salinity was considerably higher. Between 50 and 100 metres, as in the deep stations outside Trinity Opening, there was an abrupt fall in temperature and rise in salinity ; dissolved phosphate and nitrate rose, and pH value and oxygen saturation fell. Below 100 metres there was a continued steep fall in temperature, but salinity rose slightly to 200 metres before beginning to fall. At Trinity Opening, on the other hand, salinity was at its maximum at 180 metres in October and 100 metres in November. Below 100 metres a change in the steepness of the gradient also occurred outside Papuan Pass in pH value and in oxygen saturation, but apparently not in phosphate content.

The abruptness of the descent from the plateau of the Barrier Reef lagoon to the oceanic depths of the Pacific beyond the Barrier made Papuan Pass a very useful position for testing whether or not the upwelling suspected at Trinity Opening was strong, and perhaps characteristic for this part of the Barrier. In addition to sampling the deep water beyond the Barrier, therefore, samples were taken on the steep slope of the outer side of the Barrier itself. These were taken near the 100-fathom line slightly to the south of Papuan Pass (off Andersen Reef) at 50 and at 100 metres. At 50 metres the results were very similar to those at the same depth at the deeper station. At 100 metres, however, the temperature was lower, the salinity higher, the oxygen saturation lower, the pH value lower, and the phosphate content higher than at the same depth further out from the Barrier to the east. These values, similar to those found at a *greater* depth further off the Reef, suggest strongly that some upwelling was going on close to the Barrier. As at Trinity Opening, however, it is impossible to say whether upwelling is continuous there, or whether it is sufficiently accentuated at any time of the year to result in any enrichment with plant food salts of the well-illuminated surface waters. Further evidence of upwelling was obtained during a voyage from Townsville to Willis Islets (16° 0′ S., 149° 57′ E.). Samples were taken at the surface and at a depth of 80 metres, both on the seaward slope of the Barrier outside Palm Passage and in deep water five miles further east during fresh S.E. wind. The two deep samples again showed that there was a slight upwelling close to the Barrier. The weather unfortunately became so bad that it was impossible to take samples on the slopes of Willis Islets, an ideal place for testing for upwelling on oceanic coral islands.

Outside Cook's Passage.

The results obtained in the deep-water station outside Cook's Passage are shown in Text-fig. 6 and Table III. The water in the upper zone was very slightly warmer and a little more saline than in the Passage itself, but was much the same in other respects and almost homogeneous down to 50 metres. In the deeper layers the results obtained were similar to those in Papuan Pass, though at the more southerly station the upper layers had a higher temperature, caused by a few days of fine weather. Outside Cook's Passage the chief change in temperature, salinity and density occurred between 50 and 100 metres, but in oxygen saturation and phosphate content lay between 100 and 200 metres as compared with Papuan Pass and Trinity Opening, where the change was between 50 and 100 metres. The direction of the changes was, however, the same at both these stations. Whether this difference from Papuan Pass is to be attributed to the peculiarity of the current at Cook's Passage (the current runs to the north there, as contrasted with Papuan Pass and Trinity Opening, where it runs south), or whether it was caused by the unusual weather at the time the station was worked (a north wind) is not known. No observations were made at this position closer to the outside of the Barrier owing to the bad visibility and the rising wind.

So far as the scantiness of the data allow any conclusions to be drawn, it may be said that the top 50 metres some miles beyond the Barrier are essentially similar not only to the water in the passages, but also to the water inside the lagoon itself. The differences met with generally do not exceed the differences found between different positions inside the Barrier Reef lagoon. The fact that the outside water is always slightly more saline than that in the passages, is to be attributed to the fact that the water in the passages is a mixture of oceanic water with water of lower salinity from the lagoon. Even the positions outside the Barrier, however, are almost certain to have been affected by land influences to some extent. More particularly in Cook's Passage and Papuan Pass, which are narrow, there is a strong tidal current, the effect of which must extend for some miles to seaward. At Trinity Opening the breadth of the passage is relatively great, and the tidal current correspondingly weaker. Confirmation of this difference between Cook's Passage and Papuan Pass on the one hand and Trinity Opening on the other is given by the Secchi disc readings. Outside Cook's Passage the reading was only 14 metres, which was but slightly higher than in the Passage itself (12 metres) ; outside Papuan Pass it was 28 metres as against 14 metres in the Pass. Outside Trinity Opening, however, it was at least (see p. 39) 36 metres, and 40 metres on the two occasions it was examined. At almost the same date as 40 metres was recorded outside, the reading three miles east of Low Isles was only 16·5 metres. While the two northerly positions were worked during the rainy season, when there were considerable fluctuations in the salinity of the lagoon, the southerly positions were worked just before the beginning of the rainy season, and at this time both the oceanic water outside Trinity Opening and the lagoon water three miles east of Low Isles had a high salinity and were almost identical.

Between 50 and 100 metres there is an abrupt change at all three positions. This is shown chiefly in temperature and salinity. The values at 100 metres, however, are not identical in these or in other features, and differences between the stations occur even at 200 metres. The stations outside Papuan Pass and outside Cook's Passage were worked within a few days of each other, and it is therefore reasonable to conclude that hydrographic conditions along the seaward edge of the Barrier are not necessarily uniform, but may vary with position or with weather conditions. The observations at Trinity Opening were made some months earlier than at the two other positions, and therefore cannot be compared with safety with them. The important changes, however, took place between 50 and 100 metres, and it seems safe to conclude that the discontinuity layer remains at about the same depth throughout the year off the seaward edge of the Barrier.

The only unexpected feature in the water below 100 metres outside the Barrier was the change in salinity in the deeper water. Between 50 and 100 metres there was an abrupt rise corresponding with the changes in the other conditions, which show this to be about the limit of vertical mixing; this rise continued, though somewhat more gradually, to 100 or 180 metres (outside Trinity Opening) or 200 metres (outside Cook's Passage and Papuan Pass), where the maximum value was obtained (about $35{\cdot}6^{\circ}/_{\circ\circ}$). Below this the salinity again fell, due to the presence at these greater depths of water which must have a different origin from that lying above it. The stability of the water column is maintained by the decrease in temperature with depth, the curve for density rising continuously from 50 metres to the greatest depth sampled.

GENERAL SUMMARY OF CONDITIONS IN THE BARRIER REEF REGION (14° 30′ S. to 16° 30′ S.).

In the lagoon for the major part of the year (February to October) a strong S.E. wind prevails, causing a current to run north. There is considerable disturbance of the sea, and the water is kept well mixed from top to bottom during this period. During the remaining part of the year winds are lighter and may come from a northerly direction. Mixing of the water is less pronounced at this time, and calm spells are frequent. While the S.E. trade wind blows the sky is generally clear and there is bright sunshine and little or no rainfall. At other times the weather is less settled, and heavy rain and thunderstorms are frequent. The lagoon in the vicinity of Low Isles showed an annual range of temperature of about 8·6° C., while the average temperature was 25·6° C. It followed closely the variations in air temperature. The vertical gradient was small, except for short intervals in calm weather during the rainy season. The average salinity, which probably varies from year to year, was about $34{\cdot}7^{\circ}/_{\circ\circ}$, and the maximum about $35{\cdot}5^{\circ}/_{\circ\circ}$. The salinity changes were small during the period when the S.E. wind prevails, but at other times depended chiefly on rainfall. The large reductions in salinity, caused by land drainage and by rain falling on the sea, were gradually counterbalanced by a replacement by the more saline water from beyond the Barrier. The humidity is normally high and evaporation small.

The water inside the Barrier was generally turbid, the Secchi disc being visible on an average to a depth of only 12 metres. The oxygen content of the water was high, being over 90% saturation most of the time. In deeper water during the calm periods of the rainy season the saturation may fall to about 80%. In no case, however, is it likely to have affected plant or animal life injuriously. Certain plant nutrient salts (phosphates and nitrates) were present in extremely small quantities throughout the year. Silicates were present in excess of plant requirements.

There were no important variations found from one position to another inside the lagoon, within the limits of latitude studied, and it is very probable that similar conditions hold for the major part of the lagoon. This conclusion is supported by the temperature records from the S.S. "Cape Leeuwin" and S.S. "Cape York", by the known meteorological conditions and by the known currents.

On the seaward edge of the Barrier in the region examined the top 50 metres were essentially similar to the waters in the lagoon. The only important difference was that, as might be expected, a somewhat higher salinity prevailed outside the Barrier, particularly during the rainy season. Between 50 and 100 metres an abrupt change took place in almost all the conditions; temperature fell, salinity rose, pH value and oxygen saturation fell and phosphate and nitrate rose. The discontinuity layer was found at the same depth in the rainy and in the dry season. The changes in all factors except salinity continued to the greatest depth sampled (600 metres). Salinity showed a decrease with depth below 100 or 200 metres.

THE BIOLOGICAL SIGNIFICANCE OF THE PHYSICAL AND CHEMICAL CONDITIONS.

The object of the following paragraphs is to indicate the probable effect of some of the physical and chemical conditions on life in the waters of the Barrier Reef region. Detailed descriptions of the relationship of the phyto- and zooplankton to these conditions will be given in later reports in this volume by S. M. Marshall and by F. S. Russell and J. Colman respectively. Detailed descriptions of the factors affecting corals are given by C. M. Yonge and others elsewhere in these reports.

Certain factors, such as the high temperature and the fluctuations in salinity for some months of the year, will undoubtedly have an effect on the plankton. The former will cause a high rate of metabolism, and the latter will forbid the presence of certain oceanic species in the lagoon for at least part of the year. For the production of the phytoplankton, however, the vertical mixing from top to bottom in conjunction with the high light intensity and poverty of certain plant nutrient salts have a determining influence. The duration of daylight at different times of the year is approximately constant when compared with temperate latitudes, and the light intensity during the hours of daylight is high. There is thus sufficient light for photosynthesis at the surface and at least as deep as 20 metres throughout inside the Barrier, though the variations in turbidity of the sea will have an important influence on the limiting depth. No actual measurements of the depth to which photosynthesis went on were made, but from the observations on the phytoplankton, to be recorded later in this volume, it is certain that at some times photosynthesis must have gone on at depths greater than 20 metres.

On the other hand, the poverty of the sea in certain plant nutrient salts—phosphates and nitrates—will tend to limit plant production, and may possibly affect the amount of zooplankton. There is apparently seldom a complete lack of either of these salts, so that plant life is always present; the quantities, however, are too small to allow of a striking outburst of growth, such as is characteristic of temperate seas.

In the lagoon the calm periods are of too short duration to permit of any regenerated nutrient salts accumulating in quantity in the deeper waters. On one or two occasions there was a significant fall in the oxygen content, but there was no appreciable rise in dissolved phosphate. Were a calm period to persist for some considerable length of time, there is little doubt that plant food salts would accumulate in the deeper water. Such an event would give rise to a seasonal production of phytoplankton. With vertical mixing predominant for the greater part of the year, the only circumstances likely to lead to variations in the quantity of nutrient salts are winds causing exceptional disturbance of the sediment on the sea bottom.

On account of the small numbers of observations, little can be said of the conditions for the life of plankton outside the Barrier. The greater clearness of the water should allow photosynthesis at greater depths than inside, but phosphates and nitrates are again present only in very small quantities down to 50 metres. It is probable that vertical mixing extends to about this depth.

A factor which may be of importance here is the upwelling of the deep water rich in plant food salts close to the Barrier. When stations close to the Barrier were worked the upwelling was noticeable, especially when the gradient of the sea floor was very steep. The amount of phosphate at 100 metres was considerably higher close to the Barrier than further out. At the surface at both positions the values were very low, so that the upwelling had not extended as far as this. No observations were made at intermediate depths. Again the observations had to be made in calm weather, which is abnormal for this region, and it is unsafe to conclude what the effect of the fresh S.E. trade wind on upwelling would be. It is well known that abrupt changes in the contour of the sea bottom cause upwelling and enrichment of the surface waters with nutrient salts, leading to an abundance of plant and animal life. It would be interesting in this connection to investigate the seas in the neighbourhood of oceanic coral islands for upwelling.

It is an interesting and perhaps significant coincidence that the depths inside the lagoon correspond approximately with the depth to which vertical mixing goes on outside the Barrier. The maximum depth of the Barrier Reef lagoon in the neighbourhood of Low Isles is about 40 metres and vertical mixing goes on right to the bottom. Seaward of the Barrier vertical mixing goes as deep as 50 to 100 metres. Comparatively small maximum depths are characteristic of coral reef lagoons, and 99% of coral reef lagoons have a maximum depth less than 90 metres. It seems probable, then, that the vertical mixing which has such an important effect on the plankton in the lagoon of the Great Barrier Reef will be found to be common in most coral reef lagoons. Whether the disturbance of the sediment on the sea bottom, which is also an important feature of the Barrier Reef lagoon, will be common elsewhere is another matter, for in a considerable part of the Barrier Reef lagoon the bottom consists of mud (see p. 47), which will be readily disturbed, while sand, which is much less readily disturbed, is characteristic of most lagoons and of parts even of the Barrier Reef lagoon.

The influence of some physical conditions on the life of corals in the sea has already been studied in the laboratory by Mayer (1918), and by Yonge and Nicholls (Vol. I, No. 6), and from their results it is possible to infer what effect the variations taking place in the sea will have on coral survival. The temperature of the sea in the neighbourhood of Low Isles never exceeded either the maximum or the minimum for coral survival found by Mayer (1918). According to him the maximum they can survive is from 36°–38° C., and the minimum from 10°–19° C. On the flats of coral reefs, on the other hand (see the following report), these limits are closely approached, if not surpassed, for short intervals. Beyond the Barrier, in water down to 100 metres, it is improbable that these limits are reached, and the depth at which the lower limit for survival is surpassed in the region examined was as deep as 200 metres. Towards the southern limit of the Barrier Reef, however, the surface temperatures recorded by the S.S. "Cape Leeuwin" and S.S. "Cape York" approach closely to the low temperature survival limits for corals, though on reef flats in that vicinity, such limits must undoubtedly be surpassed at times.

No salinities recorded are beyond the limits tolerated by corals, though on reef flats such limits are undoubtedly surpassed at times. The complete destruction to a depth of 10 ft. below mean tide level of a coral reef during a period of very heavy rainfall is recorded by Hedley (1925*a*).

It has been shown that in the lagoon and down to between 50 to 100 metres seaward of the Barrier, the oxygen saturation generally exceeds 90%. Even in deep water beyond the Barrier it does not fall below 60 to 70%. Yonge, Yonge and Nicholls, in Vol. I, No. 8, have found that the respiration of corals is very little affected by such a small reduction in the quantity of oxygen present, and that they can survive much greater reductions for short periods. Considerably greater diminution in the oxygen content of the water takes place at times on reef flats (see the following report), but even there it is not of long enough duration to limit coral growth.

The quantity of plant nutrient salts in the sea will only affect the corals indirectly, since it is on the quantity of these that the phytoplankton, and ultimately, to some extent, the zooplankton on which the corals feed depend.

Unfortunately no measurements could be made of light intensity in the Barrier Reef region, and the only available data are Secchi disc readings. In the lagoon the turbidity is usually great, the average visibility of the Secchi disc being only about 12 metres. Outside the Barrier the water is much clearer, and Secchi disc readings as high as 40 metres were obtained. It has been shown by Yonge and Nicholls (Vol. I, No. 6) that there is a decrease in the number of zooxanthellae in the tissues of the corals at a depth of about 17 metres in the lagoon, and at this depth reef-building corals are much less abundant than at lesser depths. The greater clearness of the water beyond the Barrier would allow photosynthesis to go on to considerably greater depths, and though no accurate figure can be given on the basis of Secchi disc measurements alone, the facts that nutrient salts are probably always present between 50 and 100 metres, and that there is a very considerable change in other conditions at the same depth, suggest that the limit for growth of corals containing numerous zooxanthellae is not likely to be much greater than about 50 metres. This is in agreement with recent estimates of the depth limit of flourishing reef corals. No data are available for the richness of corals at different depths on the seaward slope of the Barrier in conjunction with Secchi disc readings, but that a correlation does exist between these two factors has been shown by Verwey (1930, 1931) for the coral islands in the Bay of Batavia. This relationship is dependent on light intensity alone, and it is improbable that the amount of sediment in the water has a direct harmful influence on the corals (see Marshall and Orr, Vol. I, No. 5). The distribution of corals with depth on Low Isles will be described elsewhere in these reports.

COMPARISON OF THE CONDITIONS IN THE BARRIER REEF REGION WITH THOSE IN OTHER LOCALITIES.

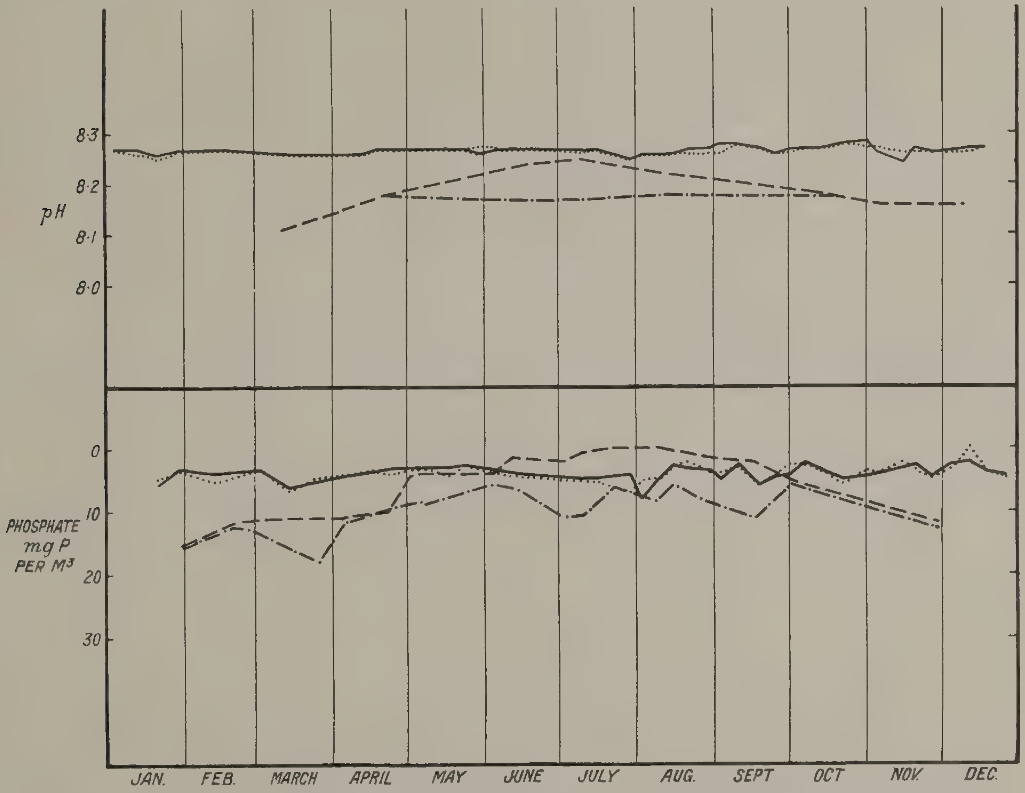
The object of the hydrographical investigations was partly to find what seasonal variations took place in the tropics, and partly also that the conditions affecting corals directly or indirectly might be studied. A comparison of the results obtained with those from other parts of the tropics confirms in the main the fact that there is, in the tropics, a considerable uniformity. Though no seasonal data are available for other parts of the tropics, a large number of observations, made for the chief part on ships making definite cruises, have already been published, and others should soon be available. Very few results, however, are available for positions in close proximity to coral reefs or in coral reef lagoons. McClendon (1918) made a number of observations of the changes in hydrogen ion concentration at Tortugas, Florida, and obtained values which are essentially similar to those obtained near Low Isles. His values for surface samples from positions not on reef flats varied from pH 8·23 to 8·30. On the reef flats there was a considerable diurnal variation, such as was found at Low Isles (see following report). Results for the tropical Pacific Ocean found by Mayer (1919) gave an average value of pH 8·22 using McClendon's method (1917). More recently, however, Ito (1928), using Palitzsch's method (1911), found values varying from pH 8·30 to 8·39 in the Pacific in 2° N. latitude. McClendon (1918) obtained a good agreement between his results and those of Palitzsch, so that Ito's results are unexpectedly high.

Oxygen results are available for two regions similar in many ways to those at Low Isles. McClendon (1918) found that the water in the Tortugas was generally slightly supersaturated with respect to oxygen during the day, but, as he worked chiefly in very shallow positions, the results are hardly comparable with those from the station three miles east of Low Isles. They are, however, of considerable interest when compared with the results from the reef flat of Low Isles recorded in the following report, as are also those of Verwey (1930, 1931), whose observations were made on the coral islands in the Bay of Batavia. The results obtained off the seaward edge of the Barrier are similar to those described by Wattenberg (1929) for 15° S. latitude in the Atlantic Ocean, *i. e.* the high surface values only extend to about 50 metres, and below this there is a rapid fall in oxygen content.

No estimations of phosphorus content are available for localities similar to the Barrier Reef region. The low values, however, are characteristic of tropical seas in general (*cf.* Hentschel and Wattenberg, 1930), and the effect on the abundance of the plankton is similar. Atkins (1926) has shown that complete utilization of the phosphate takes place in the tropical Pacific down to at least 50 metres, and that below this depth there is a considerable amount of phosphate. Though zero values were seldom obtained in the Barrier Reef region, the vertical distribution was similar on the seaward edge of the Barrier Reef to that found elsewhere in the tropical Pacific by Atkins.

The existence throughout the year of a discontinuity layer between 50 and 100 metres in the deeper water of the Barrier Reef region, and the consequent absence of any discontinuity layer in the lagoon (and probably in most coral reef lagoons), constitutes a very important difference between these waters and the sea in temperate regions. In the Barrier Reef region the winter cooling of the water is never sufficient to mix it deeper than 50 metres, so that plant nutrient salts cannot be reintroduced from the deeper layers. In temperate waters, on the other hand, the winter cooling extends much deeper than the photosynthetic zone, and fresh supplies of plant nutrient salts are introduced into the surface waters. In 38° N. latitude in the Atlantic, for example, the sea is isothermal in winter down to 350–400 metres (Atkins, 1926).

Even in the shallow waters of the Barrier Reef lagoon there is a very marked difference from shallow waters in temperate latitudes. In making the comparison, it should be remembered that the water inside the Barrier Reef lagoon, though probably typical of shallow tropical water in most respects, is bound to vary from other localities in some respects. For example, it is very much influenced by the proximity of the mainland (*e.g.* salinity). In addition, the Barrier Reef, though it acts as a breakwater in lessening the force of the waves, does not prevent the inflow of oceanic water. It is of interest, however, to compare the seasonal observations there with those made in the comparatively enclosed waters of the English Channel, and with those in more or less completely enclosed waters (*e.g.* Loch Striven in the Clyde Sea Area).



Text-fig. 7.—Seasonal variations 3 miles E. of Low Isles compared with variations in temperate waters (English Channel). (1) pH value. (2) Phosphorus. ————— Low Isles, surface. .... Low Isles, 28 metres. —— —— —— —— English Channel, surface. — · — · — · — English Channel, deep water.

The difference in average temperature between the two areas is large (about 14° C.), and must result in a very much higher rate of metabolism in the Barrier Reef lagoon. The seasonal range of temperature, however, is not very different, being 6·9° C. in the English Channel (Jee, 1919), as against 8·6° C. in the Barrier Reef lagoon in the neighbourhood of Low Isles. Nutrient salts are much less abundant in the lagoon; there is an average of about 4 mg. P. per cubic metre throughout the year, as compared with a winter value of about 14 mg. per cubic metre in the English Channel.

Apart from the temperature differences and the deficiency in plant nutrient salts, the most striking contrast between the shallow water in the two zones is the difference in seasonal changes. In the Barrier Reef lagoon there are no, or at least negligible, seasonal changes, except in temperature and salinity, and the changes in these two conditions affect generally the whole body of the water in the lagoon. Only for a short time in calm weather was the water stable, and this stability persisted for too short a time to enable any definite stratification to take place. As a consequence, pH value, phosphate content and oxygen saturation are practically the same the whole year at all depths. In the two temperate localities, on the other hand, there are marked seasonal changes, and there is also a distinct layering of the water. A comparison of the changes in pH value and phosphate content is shown in Text-fig. 7 (English Channel, Atkins, 1924, 1926) and Text-fig. 5 (Loch Striven, Marshall and Orr, 1928), where oxygen saturation is also shown. During the spring, in temperate waters, the surface stratum becomes heated to a greater extent than the deeper water. This, being lighter, tends to remain at the surface, and as warming advances, the turbulence due to winds is insufficient to mix it completely with the deeper water. The nutrient salts are rapidly used up in this well-illuminated surface stratum by the phytoplankton, and in the meantime they are being regenerated in deeper water by decomposition and by the zooplankton. In the autumn, cooling of the surface layers leads to a mixing of the strata and a re-introduction of nutrient salts into the surface layers again. In addition to removing the nutrient salts, the photosynthesis of the phytoplankton leads to an increase in the degree of oxygenation and of the pH value of the surface waters, while a reverse effect is caused in the deep water by the zooplankton and by decomposition.

REFERENCES.

Atkins, W. R. G. 1923*a*. The Phosphate Content of Fresh and Salt Waters in its Relationship to the Growth of the Algal Plankton. J. Mar. Biol. Ass. U.K. XIII, pp. 119–150, text illust.

—— 1923*b*. The Silica Content of Some Natural Waters and Culture Media. J. Mar. Biol. Ass. U.K. XIII, pp. 151–159, text illust.

—— 1923*c*. Note on the Oxidisable Organic Matter of Sea-water. J. Mar. Biol. Ass. U.K. XIII, pp. 160–163.

—— 1924. The Hydrogen Ion Concentration of Sea-water in its relation to Phytosynthetic Changes. Part III. J. Mar. Biol. Ass. U.K. XIII, pp. 437–446, figs. 1–4.

—— 1926. The Phosphate Content of Sea-water in Relation to the Growth of Algal Plankton. Part III. J. Mar. Biol. Ass. U.K. XIV, pp. 447–467, 5 figs.

—— and Wilson, E. G. 1927. The Phosphorus and Arsenic Compounds of Sea-water. J. Mar. Biol. Ass. U.K. XIV, pp. 609–614.

'Australia Pilot.' 1928. IV, pp. i–xxii, 1–258, text illust. London.

Bigelow H. B., and Leslie, M. 1930. Reconnaissance of the Waters and Plankton of Monterey Bay, July, 1928. Bull. Mus. Comp. Zool. Harv. LXX, No. 5, pp. 429–581, text illust.

Davis, W. M. 1928. The Coral Reef Problem. Sp. Pub. Amer. Geogr. Soc. No. 9, pp. v, 596, 15 pls., text illust. New York.

Denigès, G. 1920. Réaction de coloration extrêmement sensible des phosphates et des arséniates. Ses applications. C. R. Acad. Sci. Paris, CLXXI, pp. 802–804.

—— 1921. Détermination quantitative des plus faibles quantités de phosphates dans les produits biologiques par la méthode céruléomolybdique. C. R. Soc. Biol. Paris, LXXXIV, pp. 875–877.

Diénert, F., et Wandenbulcke, F. 1923. Sur le dosage de la silice dans les eaux. C. R. Acad. Sci. Paris, CLXXVI, pp. 1478–1480.

Fox, C. J. J. 1907. On the Coefficients of Absorption of the Atmospheric Gases in Distilled Water and Sea-water. Part I: Nitrogen and Oxygen. Pub. Circ. Explor. Mer, No. 41, pp. 4, 23, 1 pl.

Gran, H. H., and Ruud, B. 1926. Untersuchungen über die im Meerwasser gelösten organischen Stoffe und ihr Verhältnis zur Planktonproduktion. Avh. Norske Vid. Akad. Oslo. I. Matem.-Naturvid. Klasse, No. 6, pp. 14.

HARVEY, H. W. 1925. Evaporation and Temperature Changes in the English Channel. J. Mar. Biol. Ass. U.K. XIII, pp. 678–692, text illust.

—— 1926. Nitrate in the Sea : I. J. Mar. Biol. Ass. U.K. XIV, pp. 71–88, text illust.

—— 1928*a*. Nitrate in the Sea : II. J. Mar. Biol. Ass. U.K. XV, pp. 183–190, text illust.

—— 1928*b*. Biological Chemistry and Physics of Sea-water, pp. 194, text illust. Cambridge.

HEDLEY, C. 1925*a*. The Natural Destruction of a Coral Reef. Trans. R. Geogr. Soc. Aust. (Queensland). Reports of the Great Barrier Reef Committee, I, pp. 35–40, pl. v, text illust.

—— 1925*b*. An Opacity Meter. Trans. R. Geogr. Soc. Aust. (Queensland). Reports of the Great Barrier Reef Committee, I, pp. 67–68, pl. xvi.

HENTSCHEL, E., and WATTENBERG, H. 1930. Plankton und Phosphat in der Oberflächenschicht des Südatlantischen Ozeans. Ann. d. Hydr. u Maritim. Meteorol. VIII, pp. 273–277, 3 charts.

ITO, K. 1928. Hydrogen-ion Concentration of Sea-water in the South-western Portion of the North Pacific. Rec. Oceanogr. Works in Japan, I, No. 2, pp. 90–94, text illust.

JEE, E. C. 1919. Hydrography of the English Channel. Part I : Start Point to the Channel Islands. Fish. Invest. London, Series III, I, pp. 3–76.

JOHNSON, D. W. 1919. Shore Processes and Shore Line Development, pp. xvii, 584, text illust. London.

KING, E. J., and LUCAS, C. C. 1928. The Use of Picric Acid as an Artificial Standard in the Colorimetric Estimation of Silica. J. Amer. Chem. Soc. L, pp. 2395–2397.

KNUDSEN, M. 1901. Hydrographical Tables, pp. 63. London.

—— 1923. Some New Oceanographical Instruments. Pub. Circ. Explor. Mer, No. 77, pp. 1–16, text illust.

McCLENDON, J. F. 1917. The Standardisation of a New Colorimetric Method for the Determination of the Hydrogen Ion Concentration, CO_2 Tension, and CO_2 and O_2 Content of Sea-water, of Animal Heat and of CO_2 of the Air, with a Summary of Similar Data on Bicarbonate Solutions in General. J. Biol. Chem. XXX, pp. 265–288, text illust.

—— 1918. On Changes in the Sea and their Relation to Organisms. Pap. Dept. Mar. Biol. Carn. Instn. XII, pp. 213–258, text illust.

MARSHALL, S. M., and ORR, A. P. 1927. The Relation of the Plankton to some Chemical and Physical Factors in the Clyde Sea Area. J. Mar. Biol. Ass. U.K. XIV, pp. 837–868, 10 pls., 9 figs.

—— —— 1930. A Study of the Spring Diatom Increase in Loch Striven. J. Mar. Biol. Ass. U.K. XVI, pp. 853–878, text illust.

MAYER, A. G. [afterwards MAYOR.]. 1918. Ecology of the Murray Island Coral Reef. Pap. Dept. Mar. Biol. Carn. Instn. IX, pp. 1–48, pls. 1–19, text illust.

—— 1919. Detecting Ocean Currents by Observing the Hydrogen Ion Concentration. Proc. Amer. Phil. Soc. LVIII, pp. 150–160.

MOBERG, E. G. 1928. The Inter-relation between Diatoms, their Chemical Environment and Upwelling Waters in the Sea, off the Coast of Southern California. Proc. Nat. Acad. Sci. Wash. XIV, No. 7, pp. 511–518, 1 fig.

PALITZSCH, S. 1911. Ueber die Messung der Wasserstoffionen-konzentration des Meerwassers. Pub. Circ. Explor. Mer, No. 60, pp. 27.

POOLE, H. H., and ATKINS, W. R. G. 1928. Further Photo-electric Measurements of the Penetration of Light into Sea-water. J. Mar. Biol. Ass. U.K. XV, pp. 455–483, 1 pl., text illust.

RUPPIN, E. 1904. Ueber die Oxidierbarkeit des Meerwassers durch Kaliumpermanganat. Pub. Circ. Explor. Mer, No. 20, p. 9, text illust.

RUSSELL, F. S. 1928. The Vertical Distribution of Marine Macroplankton. VII : Observations on the Behaviour of *Calanus finmarchicus*. J. Mar. Biol. Ass. U.K. XV, pp. 429–454, text illust.

SPENDER, M. A. 1930. Island Reefs of the Queensland Coast. Geogr. J. LXXVI, pp. 193–214, 10 pls., text illust ; pp. 273–297, 8 pls., text illust., 2 maps.

STEERS, J. A. 1929. The Queensland Coast and the Great Barrier Reefs. Geogr. J. LXXIV, pp. 232–257, 4 pls., text illust. ; pp. 341–370, 4 pls., text illust.

TYDEMAN, G. F. 1903. Hydrographic Results of the Siboga Expedition. Siboga-Expeditie, III, 1899–1900, pp. 1–93, text illust., 27 charts, Leiden.

VERWEY, J. 1930. Depth of Coral Reefs and Penetration of Light. With Notes on Oxygen Consumption of Corals. Proc. Fourth Pacif. Sci. Cong. Batavia, IIA, pp. 277–294, 5 pls.

—— 1931. Coral Reef Studies. II : The Depth of Coral Reefs in Relation to their Oxygen Consumption and the Penetration of Light in the Water. Treubia, XIII, pp. 169–198, text illust.

WATTENBERG, H. 1929. Die Durchlüftung des Atlantischen Ozeans. J. Con. Int. Explor. Mer, IV, pp. 68–79, 4 figs.

Table I.—*Position Three Miles East of Low Isles.*

Station.	Date.	Time.	Sounding (metres).	Sea.	Weather.	Remarks.
H. 3	30.vii.28	8.13 a.m.	32·5	Lumpy	Clear	..
H. 4	4.viii.28	7.38 ,,	31·5	,,	,,	..
H. 6	11.viii.28	7.40 ,,	32·5	,,	,,	..
H. 7	16.viii.28	8.42 ,,	32	,,	,,	..
H. 11	22.viii.28	8 ,,	32	,,	,,	..
H. 13	31.viii.28	10.02 ,,	32	,,	,,	..
H. 14	4.ix.28	7.45 ,,	32·5	,,	,,	..
H. 16	11.ix.28	8.15 ,,	32·5	Calm to lumpy	Light haze	..
H. 17	20.ix.28	8.10 ,,	32	Lumpy	Clear	..
H. 18	26.ix.28	7.50 ,,	32	,,	,,	..
H. 19	2.x.28	7.50 ,,	32·2	,,	,,	..
H. 20	8.x.28	1.20 p.m.	32	Rippled	,,	..

TABLE I.—*Hydrographical Observations.*

Station.	Depth (metres).	Temperature (° C.).	Secchi disc (metres).	S. °/₀₀.	σ_t.	pH.	P. (mg. per m^3).	Nitrate (mg. N_2 per m^3).	Silicate (mg. per m^3).	Oxygen (c.c. per l).	Oxygen saturation (%).	Oxidizable organic matter (mg. per l).
H. 3	28	22·57	5·5	35·19	24·21	8·25	6·6	..	..	4·72	92·3	..
	20	22·58	..	35·21	24·23	8·25	6·1	..	..	4·75	93·0	..
	15	22·57	..	35·21	24·23	8·25	6·1	..	..	4·75	93·0	..
	10	22·58	..	35·16	24·18	8·25	6·6	..	..	4·75	92·9	..
	5	22·57	..	35·16	24·18	8·25	6·6	..	..	4·66	91·2	..
	0	22·58	..	35·16	24·18	8·25	4·4	..	..	4·76	93·1	..
H. 4	28	22·29	10	35·10	24·23	8·26	4·8	..	..	4·80	93·4	0·97
	20	22·28	..	35·10	24·23	8·26	4·8	..	..	4·81	93·4	0·31
	15	22·28	..	35·10	24·23	8·26	5·2	..	..	4·90	93·4	..
	10	22·28	..	35·08	24·21	8·26	..	..	..	4·89	93·4	0·51
	5	22·20	..	35·08	24·24	8·26	7·9	..	..	4·83	93·8	0·55
	0	22·20	..	35·03	24·20	8·26	7·9	..	..	4·84	94·0	0·49
H. 6	28	21·51	8	34·94	24·33	8·26	4·6	..	..	4·85	92·8	..
	20	21·52	..	34·91	24·31	8·26	5·1	..	..	4·89	93·5	..
	15	21·52	..	34·92	24·31	8·26	5·1	..	..	4·93	94·2	..
	10	21·52	..	34·91	24·31	8·26	4·7	..	..	4·93	94·2	..
	5	21·53	..	34·93	24·32	8·26	5·3	..	..	4·88	93·4	..
	0	21·53	..	34·93	24·32	8·26	4·5	..	..	4·93	94·2	..
H. 7	28	21·70	8·5	34·97	24·30	8·26	2·6	..	..	4·82	92·7	..
	20	21·70	..	34·98	24·31	8·26	2·6	..	..	3·87	93·7	..
	15	21·71	..	34·98	24·31	8·26	2·6	..	..	4·87	93·7	..
	10	21·71	..	35·00	24·32	8·26	3·1	..	..	4·87	93·7	..
	5	21·72	..	35·01	24·33	8·26	2·6	..	..	4·84	93·3	..
	0	21·73	..	34·99	24·31	8·26	2·6	..	..	4·87	93·7	..
H. 11	28	22·43	9	35·26	24·33	8·26	2·2	..	..	4·81	93·8	..
	20	22·42	..	35·27	24·33	8·27	2·2	..	..	4·75	92·6	..
	15	22·42	..	35·28	24·33	8·27	2·2	..	..	5·01	97·6	..
	10	22·42	..	35·24	24·31	8·27	2·2	..	..	4·85	94·5	..
	5	22·42	..	35·23	24·30	8·26	2·2	..	..	4·92	95·8	..
	0	22·42	..	35·24	24·31	8·27	3·1	..	..	4·91	95·7	..
H. 13	28	23·01	6·5	35·19	24·10	8·26	3·9	..	..	4·77	94·1	0·30
	20	23·01	..	35·19	24·10	8·28	3·9	..	..	4·85	95·6	0·44
	15	23·00	..	35·18	24·10	8·28	3·9	..	..	4·84	95·5	0·43
	10	23·00	..	35·19	24·10	8·27	3·5	..	..	4·85	95·6	0·45
	5	23·07	..	35·19	24·07	8·28	3·1	..	..	4·88	96·4	0·45
	0	23·02	..	35·19	24·10	8·27	3·5	..	..	4·86	96·3	0·41
H. 14	28	23·29	17	35·30	24·09	8·26	3·9	..	..	4·77	94·5	..
	20	23·29	..	35·26	24·07	8·27	3·5	..	..	4·80	95·0	..
	15	23·31	..	35·26	24·07	8·26	3·9	..	..	4·82	95·4	..
	10	23·45	..	35·26	24·01	8·27	3·9	..	..	4·82	95·8	..
	5	23·47	..	35·27	24·01	8·27	5·2	..	..	4·79	95·2	..
	0	23·48	..	35·26	24·01	8·28	5·2	..	..	4·83	95·9	..
H. 16	28	24·04	20	35·26	23·86	8·28	14·0	..	..	4·79	96·0	..
	20	24·04	..	35·25	23·84	8·28	3·1	..	..	4·87	97·6	..
	15	24·10	..	35·30	24·86	8·28	2·6	..	..	4·82	96·9	..
	10	24·13	..	35·27	24·84	8·28	2·6	..	..	4·84	97·2	..
	5	24·14	..	35·30	24·86	8·28	2·6	..	..	4·79	96·3	..
	0	24·16	..	35·25	23·78	8·28	2·6	..	..	4·83	97·2	..
H. 17	28	24·53	9	35·35	23·78	8·27	5·2	..	59	4·76	96·3	..
	20	24·53	..	35·34	23·77	8·27	5·2	..	..	4·74	95·9	..
	15	24·53	..	35·31	23·75	8·27	5·2	..	43	4·75	96·0	..
	10	24·53	..	35·30	23·74	8·27	5·2	..	54	4·76	96·2	..
	5	24·53	..	35·29	23·73	8·27	5·2	..	58	4·77	96·3	..
	0	24·53	..	35·32	23·75	8·27	5·2	..	50	4·83	97·7	..
H. 18	28	25·03	13	35·39	23·66	8·26	4·4	..	..	4·75	97·0	..
	20	25·11	..	35·36	23·61	8·26	4·4	..	..	4·80	98·0	..
	15	25·11	..	35·35	23·60	8·26	4·4	..	..	4·79	98·0	..
	10	25·11	..	35·35	23·60	8·26	4·4	..	..	4·78	97·7	..
	5	25·12	..	35·34	23·59	8·26	4·4	..	..	4·80	98·1	..
	0	25·16	..	35·39	23·60	8·26	4·4	..	..	4·77	97·8	..
H. 19	28	25·08	9·5	35·36	23·61	8·26	2·6	..	..	4·61	94·3	..
	20	25·08	..	35·37	23·62	8·26	2·6	..	..	4·62	94·5	..
	15	25·09	..	35·39	23·63	8·27	3·9	..	..	4·67	95·4	..
	10	25·10	..	35·38	23·63	8·26	3·9	..	..	4·67	95·5	..
	5	25·10	..	35·36	23·61	8·27	3·9	..	..	4·64	94·8	..
	0	25·16	..	35·37	23·59	8·27	3·9	..	..	4·67	95·7	..
H. 20	28	25·27	12	35·36	23·55	8·27	2·6	..	..	4·70	96·5	..
	20	25·29	..	35·35	23·54	8·27	2·6	..	..	4·71	96·7	..
	15	25·30	..	35·35	23·54	8·27	2·6	..	..	4·71	96·7	..
	10	25·40	..	35·35	23·50	8·27	2·6	..	..	4·68	96·1	..
	5	25·84	..	35·37	23·40	8·27	2·6	..	..	4·78	99·0	..
	0	25·56	..	35·37	23·46	8·27	2·2	..	..	4·67	98·1	..

TABLE I.—*Position Three Miles East of Low Isles* (continued).

Station.	Date.	Time.	Sounding (metres).	Sea.	Weather.	Remarks.
H. 21	15.x.28	Surface and 5 m. at 8.30 a.m. Others at 12 noon	32	Lumpy	Clear; dull later	.. ..
H. 24	23.x.28	7.30 a.m.	32·5	Calm	Clear	..
H. 25	2.xi.28	11.21 ,,	32	,,	Light clouds	..
H. 26	6.xi.28	8 ,,	32	Rippled	,,	..
H. 27	16.xi.28	11.40 ,,	32	Fairly calm	Clear	..
H. 29	21.xi.28	7.43 ,,	31	Slight sea	,,	..
H. 32	28.xi.28	9.35 ,,	32·5	Rough	Overcast	Secchi disc 9 m. on 29.xi.28.
H. 33	5.xii.28	7.50 ,,	32	Rippled	Clear	..
H. 34	13.xii.28	4.48 p.m.	30·5	Lumpy	,,	..
H. 35	19.xii.28	9.50 a.m.	32	Rippled	,,	..
H. 36	27.xii.28	9 ,,	32	,,	,,	..

TABLE I.—*Hydrographical Observations* (continued).

Station.	Depth (metres).	Temperature (° C.).	Secchi disc (metres).	S. °/₀₀.	σ_t.	pH.	P. (mg. per m³).	Nitrate (mg. N_2 per m³).	Silicate (mg. per m³).	Oxygen (c.c. per l).	Oxygen saturation (%).	Oxidizable organic matter (mg. per l).
H. 21	27	25·90	7	35·39	23·38	8·27	3·5	..	..	4·63	96·0	..
	20	25·90	..	35·39	23·38	8·28	3·9	..	..	4·66	96·6	..
	15	25·90	..	35·47	23·45	8·27	3·5	..	..	..	..	..
	10	25·93	..	35·41	23·40	8·27	3·5	..	..	4·66	96·8	..
	5	25·87	..	35·39	23·38	8·27	3·5	..	..	4·64	96·3	..
	0	26·11 (noon)	..	35·40	23·32	8·27	3·5	..	..	4·68	97·0	..
	0	25·88 (8.30 a.m.)	..	35·44	23·42	8·27	3·5	..	..	4·62	96·0	..
H. 24	28	26·23	20·5	35·27	23·20	8·28	5·7	..	..	4·67	97·3	..
	20	26·40	..	35·34	23·18	8·28	4·4	..	..	4·62	96·7	..
	15	26·42	..	35·30	23·15	8·28	4·4	..	..	4·66	97·6	..
	10	26·50	..	35·30	23·12	8·28	3·9	..	..	..	..	..
	5	26·50	..	35·27	23·10	8·29	3·9	..	..	4·64	97·1	..
	0	26·68	..	35·30	23·06	8·28	4·8	..	..	4·63	97·3	..
H. 25	28	26·89	18	35·33	23·02	8·27	3·5	..	..	4·68	98·7	..
	20	27·24	..	35·27	22·88	8·27	3·5	..	..	4·66	98·8	..
	15	27·23	..	35·25	22·86	8·27	3·5	..	..	4·67	99·0	..
	10	27·24	..	35·20	22·83	8·28	3·5	..	..	4·69	99·4	..
	5	27·38	..	35·26	22·81	8·28	3·9	..	..	4·65	99·0	..
	0	27·51	..	35·28	22·78	8·28	4·4	..	..	4·86	103·5	..
H. 26	28	26·76	17·5	35·26	23·00	8·27	3·9	..	113	4·62	97·0	..
	20	26·80	..	35·24	22·98	8·27	3·9	..	81	4·63	97·2	..
	15	26·88	..	35·25	22·95	8·28	3·9	..	110	4·63	97·6	..
	10	27·33	..	35·26	22·84	8·28	3·9	..	109	4·62	98·0	..
	5	27·61	..	35·26	22·75	8·28	3·9	..	82	4·59	97·8	..
	0	27·61	..	34·78	22·38	8·26	3·9	..	94	4·62	98·1	..
H. 27	28	26·50	5·5	35·12	22·99	8·26	2·2	..	..	4·49	93·7	0·70
	20	26·50	..	35·08	22·96	8·25	3·1	..	..	4·50	94·0	0·57
	15	26·52	..	35·06	22·94	8·24	3·9	..	..	4·49	93·8	0·66
	10	26·57	..	35·06	22·90	8·24	3·9	..	..	4·51	94·4	0·69
	5	26·61	..	35·05	22·89	8·24	3·9	..	..	4·54	95·0	0·68
	0	26·88	..	34·99	22·77	8·24	3·1	..	..	4·59	96·5	0·54
H. 29	28	26·77	16·5	35·23	22·97	8·26	3·5	..	..	4·46	93·8	0·34
	20	26·80	..	35·19	22·94	8·26	3·5	..	..	4·49	94·4	0·40
	15	26·82	..	35·22	22·97	8·26	3·5	..	..	4·49	94·4	0·50
	10	26·90	..	35·21	22·93	8·26	3·5	..	..	4·51	94·8	0·43
	5	26·96	..	35·18	22·88	8·26	3·5	..	..	4·49	94·8	0·46
	0	27·00	..	35·19	22·88	8·27	2·6	..	..	4·49	94·7	0·47
H. 32	28	27·06	*c*. 12	35·22	22·88	8·26	4·8	..	..	4·52	95·5	..
	20	27·32	..	35·22	22·81	8·26	4·8	..	..	4·57	97·0	..
	15	27·32	..	35·20	22·79	8·26	4·8	..	..	4·55	96·6	..
	10	27·34	..	35·16	22·75	8·27	4·8	..	..	4·56	96·8	..
	5	27·40	..	35·21	22·77	8·27	4·4	..	..	4·56	97·0	..
	0	27·19	..	34·68	22·43	8·26	4·4	..	..	4·62	97·9	..
H. 33	28	27·50	16	35·32	22·81	..	3·5	..	..	4·54	97·0	..
	20	27·51	..	35·30	22·80	..	3·1	..	..	4·60	98·0	..
	15	27·51	..	35·28	22·78	..	2·6	..	..	4·58	97·7	..
	10	27·57	..	35·28	22·75	..	2·6	..	..	4·55	96·9	..
	5	27·63	..	35·27	22·75	..	2·6	..	..	4·59	97·8	..
	0	27·83	..	35·28	22·69	..	2·6	..	..	4·58	98·0	..
H. 34	28	27·94	11	35·35	22·71	8·26	0	..	..	4·46	95·9	..
	20	27·97	..	35·26	22·62	8·26	0	..	..	4·52	97·1	..
	15	28·00	..	35·25	22·60	8·27	Trace	..	..	4·42	95·0	..
	10	28·17	..	35·24	22·53	8·27	2·2	..	..	4·55	98·2	..
	5	28·34	..	35·24	22·50	8·26	2·2	..	..	4·50	97·4	..
	0	28·33	..	35·25	22·50	8·27	2·2	..	..	4·55	98·4	..
H. 35	28	28·00	20	35·17	22·55	8·27	3·9	..	..	4·45	95·7	..
	20	28·13	..	35·15	22·49	8·27	3·9	..	..	4·50	97·0	..
	15	28·20	..	35·16	22·46	8·28	3·9	..	..	4·51	97·4	..
	10	28·42	..	35·06	22·32	8·27	3·9	..	..	4·57	98·9	..
	5	28·50	..	35·01	22·26	8·28	3·9	..	..	4·54	98·4	..
	0	28·73	..	35·05	22·21	8·27	3·9	..	..	4·55	98·8	..
H. 36	28	28·53	17	35·08	22·31	..	4·8	..	..	4·32	93·7	..
	20	28·58	..	35·04	22·24	..	4·4	..	..	4·38	95·0	..
	15	28·64	..	35·07	22·26	..	4·4	..	..	4·38	95·0	..
	10	29·43	..	35·05	21·98	..	4·4	..	..	4·37	95·9	..
	5	29·53	..	35·16	22·03	..	4·4	..	..	4·41	97·1	..
	0	29·65	..	35·03	21·87	..	4·4	..	..	4·40	97·2	..

TABLE I.—*Position Three Miles East of Low Isles* (continued).

Station.	Date.	Time.	Sounding (metres).	Sea.	Weather.	Remarks.
H. 37	4.i.29	12.40 p.m.	32	Choppy	Overcast	..
H. 38	14.i.29	7.20 a.m.	31	Rippled	,,	..
H. 39	21.i.29	8.5 ,,	32	Light swell	,,	..
H. 40	30.i.29	8.15 ,,	31	Rippled	Clear	..
H. 41	9.ii.29	4.3 p.m.	33	,,	,,	..
H. 42	13.ii.29	7.40 a.m.	31	,,	,,	..
H. 43	18.ii.29	7.40 ,,	31	,,	,,	..
H. 44	4.iii.29	7.30 ,,	31	,,	,,	..
H. 50	15.iii.29	11.23 ,,	30	Moderate	,,	..
H. 54	25.iii.29	8.20 ,,	33	Lumpy	,,	..
H. 55	5.iv.29	8 ,,	32	Moderate	Overcast	..
H. 56	13.iv.29	8.5 ,,	32·5	Lumpy	Clear	..

TABLE I.—*Hydrographical Observations* (continued).

Station.	Depth (metres).	Temperature° (C.).	Secchi disc (metres).	S. ‰.	σ_t.	pH.	P. (mg. per m^3).	Nitrate (mg. N_2 per m^3).	Silicate (mg. per m^3).	Oxygen (c.c. per l).	Oxygen saturation (%).	Oxidizable organic matter (mg. per l).
H. 37	28	28·40	10	35·00	22·29	8·27	..	..	..	4·21	91·1	..
	20	28·41	..	35·02	22·30	8·26	..	..	..	4·25	91·9	..
	15	28·50	..	34·99	22·24	8·27	..	..	..	4·33	93·9	..
	10	28·56	..	34·95	22·18	8·27	..	..	..	4·35	94·2	..
	5	28·60	..	34·90	22·14	8·27	..	..	..	4·38	94·8	..
	0	28·61	..	34·82	22·07	8·27	..	..	..	4·37	94·6	..
H. 38	28	28·42	15·5	34·83	22·16	8·26	..	..	83	4·01	86·6	..
	20	28·51	..	34·71	22·04	8·27	..	..	101	4·00	86·4	..
	15	28·49	..	34·58	21·94	8·27	..	..	78	4·16	89·9	..
	10	28·47	..	34·43	21·82	8·27	..	..	92	4·22	91·1	..
	5	28·40	..	34·28	21·74	8·27	..	..	76	4·26	91·6	..
	0	28·40	..	34·34	21·79	8·27	..	..	69	4·25	91·4	..
H. 39	28	28·29	19	35·00	22·32	8·25	4·8	..	..	4·03	86·9	0·77
	20	28·50	..	34·79	22·09	8·26	4·4	..	..	4·34	93·9	0·57
	15	28·80	..	34·61	21·87	8·26	4·8	..	..	4·32	93·4	1·00
	10	28·94	..	34·50	21·74	8·27	4·8	..	..	4·40	95·4	0·71
	5	29·37	..	33·95	21·16	8·26	4·8	..	..	4·38	95·6	0·77
	0	29·34	..	33·92	21·17	8·26	5·7	..	..	4·42	96·3	0·67
H. 40	28	28·75	14	34·49	21·76	8·27	3·5	..	..	4·21	91·4	..
	20	28·98	..	34·02	21·36	8·27	3·5	..	..	4·34	94·2	..
	15	28·90	..	33·83	21·25	8·27	3·1	..	..	4·37	94·3	..
	10	28·89	..	33·82	21·24	8·27	3·1	..	..	4·41	95·3	..
	5	28·88	..	33·84	21·25	8·28	3·1	..	..	4·39	94·7	..
	0	28·90	..	33·78	21·21	8·27	3·1	..	..	4·41	95·3	..
H. 41	28	28·30	19	34·21	21·72	8·27	..	..	..	4·18	89·5	..
	20	28·43	..	33·73	21·33	8·26	..	..	..	4·56	97·7	..
	15	28·40	..	33·52	21·18	8·27	..	..	..	4·49	96·2	..
	10	28·48	..	33·49	21·12	8·27	..	..	..	4·57	97·9	..
	5	28·52	..	33·49	21·12	8·26	..	..	..	4·53	96·9	..
	0	29·32	..	32·56	20·15	8·27	..	..	..	4·58	98·6	..
H. 42	28	28·30	25	34·67	22·07	8·27	5·3	..	..	4·28	92·0	..
	20	28·33	..	34·58	22·00	8·27	4·8	..	..	4·34	93·3	..
	15	28·72	..	34·00	21·44	8·27	4·4	..	..	4·42	95·4	..
	10	28·64	..	33·63	21·20	8·27	4·4	..	..	4·39	94·2	..
	5	28·83	..	33·52	21·05	8·27	4·4	..	..	4·38	94·5	..
	0	29·87	..	31·32	19·03	8·27	3·9	..	..	4·44	96·1	..
H. 43	28	27·87	22·5	34·58	22·13	8·27	..	50	..	4·23	90·1	0·59
	20	28·45	..	34·54	21·91	8·27	..	..	..	4·45	96·1	0·56
	15	28·86	..	34·04	21·39	8·27	..	..	..	4·46	96·5	0·54
	10	29·00	..	33·63	21·07	8·27	..	..	..	4·51	97·6	0·53
	5	29·49	..	33·52	20·81	8·27	..	..	..	4·47	97·5	0·67
	0	29·88	..	31·35	19·04	8·27	..	..	..	4·44	96·2	0·54
H. 44	28	28·12	16	34·50	22·00	..	3·5	..	..	4·10	87·8	..
	20	28·20	..	34·41	21·90	..	3·5	..	..	4·19	89·8	..
	15	28·39	..	34·05	21·57	..	3·5	..	..	4·26	91·5	..
	10	28·42	..	34·02	21·55	..	3·5	..	..	4·28	91·8	..
	5	28·43	..	34·02	21·55	..	3·5	..	..	4·29	92·1	..
	0	28·34	..	33·97	21·55	..	3·5	..	..	4·32	92·4	..
H. 50	28	28·20	3·5	33·55	21·26	8·26	6·6	..	..	4·34	92·6	..
	20	28·20	..	33·52	21·25	8·26	6·1	..	..	4·33	92·0	..
	15	28·22	..	33·49	21·22	8·26	6·1	..	..	4·36	92·8	..
	10	28·27	..	33·49	21·21	8·26	6·1	..	..	4·38	93·4	..
	5	28·29	..	33·45	21·18	8·25	6·1	..	..	4·39	93·6	..
	0	29·33	..	33·45	20·82	8·26	6·1	..	..	4·39	95·2	..
H. 54	28	27·79	4·5	33·38	21·26	8·26	4·8	..	..	4·32	91·2	..
	20	27·68	..	32·95	20·98	8·26	5·2	..	..	4·42	92·8	..
	15	27·68	..	32·96	20·99	8·26	7·0	..	..	4·44	93·6	..
	10	27·68	..	32·91	20·94	8·26	4·8	..	..	4·53	95·2	..
	5	27·68	..	32·91	20·94	8·26	5·2	..	..	4·44	93·4	..
	0	27·72	..	32·91	20·94	8·26	5·2	..	..	4·46	93·9	..
H. 55	28	27·78	12·5	34·45	22·06	8·26	4·4	..	..	4·16	88·6	..
	20	27·78	..	34·10	21·80	8·26	4·4	..	..	4·22	89·4	..
	15	27·77	..	33·78	21·57	8·26	4·4	..	..	4·25	89·8	..
	10	27·62	..	32·55	20·70	8·26	4·4	..	..	4·40	92·0	..
	5	27·61	..	32·50	20·67	8·26	3·9	..	..	4·42	92·5	..
	0	27·60	..	32·49	20·67	8·26	4·4	..	..	4·41	92·3	..
H. 56	28	27·00	8	33·76	21·81	8·26	..	..	..	4·41	92·1	..
	20	26·99	..	33·74	21·79	8·26	..	..	..	4·40	91·9	..
	15	26·93	..	33·68	21·77	8·26	..	..	..	4·42	92·1	..
	10	26·90	..	33·59	21·72	8·26	..	..	..	4·43	92·2	..
	5	26·90	..	33·64	21·75	8·26	..	..	..	4·44	92·5	..
	0	26·90	..	33·61	21·73	8·26	..	..	..	4·43	92·2	..

TABLE I.—*Position Three Miles East of Low Isles* (continued).

Station.	Date.	Time.	Sounding (metres).	Sea.	Weather.	Remarks.
H. 57	20.iv.29	10.15 a.m.	31	Lumpy	Overcast	..
H. 58	26.iv.29	8 ,,	31	Rippled	Clear	..
H. 59	7.v.29	10.8 ,,	31	Rough	,,	Strong drift.
H. 60	18.v.29	7.35 ,,	32	Calm	,,	..
H. 61	25.v.29	7.50 ,,	31·5	Lumpy	,,	..
H. 62	31.v.29	7.35 ,,	31·5	,,	Overcast, clearing later	..
H. 63	7.vi.29	7.50 ,,	31	,,	Clear	..
H. 64	14.vi.29	3.40 p.m.	31	Rough	Cloudy	..
H. 65	24.vi.29	1.45 ,,	32·5	,,	Clear	..
H. 66	5.vii.29	8.50 a.m.	32	Moderate to rough	,,	..
H. 67	11.vii.29	12.35 p.m.	30	Rippled	,,	..
H. 68	17.vii.29	9.50 a.m.	32	Lumpy	,,	..

TABLE I.—*Hydrographical Observations* (continued).

Station.	Depth (metres).	Temperature (° C.).	Secchi disc (metres).	S. ‰.	σ_t.	pH.	P. (mg. per m³).	Nitrate (mg. N_2 per m³).	Silicate (mg. per m³).	Oxygen (c.c. per l).	Oxygen saturation (%).	Oxidizable organic matter (mg. per l).
H. 57	28	25·96	4	33·62	22·02	8·27	..	..	..	4·54	93·1	..
	20	25·95	..	33·61	22·01	8·27	..	..	..	4·58	92·6	..
	15	25·94	..	33·56	22·00	8·27	..	..	..	4·55	92·9	..
	10	25·96	..	33·56	21·97	8·27	..	..	..	4·56	93·5	..
	5	25·98	..	33·52	21·95	8·27	..	..	..	4·56	93·4	..
	0	25·97	..	33·56	21·97	8·27	..	..	..	4·55	93·3	..
H. 58	28	26·40	18	34·54	22·58	8·27	3·9	78	..	4·38	90·8	..
	20	26·40	..	34·46	22·52	8·27	3·9	..	..	4·41	91·6	..
	15	26·47	..	34·17	22·27	8·27	3·1	..	..	4·79	99·5	..
	10	26·52	..	34·07	22·20	8·27	3·1	..	..	4·56	94·6	..
	5	26·24	..	33·56	21·91	8·27	3·1	..	..	4·80	98·7	..
	0	26·24	..	33·61	21·95	8·27	3·1	34	..	4·61	95·0	..
H. 59	28	25·26	5	34·23	22·69	8·27	3·1	..	..	4·61	93·6	..
	20	25·28	..	34·23	22·69	8·27	3·1	..	..	4·63	93·9	..
	15	25·28	..	34·25	22·70	8·27	3·1	..	..	4·63	94·0	..
	10	25·27	..	34·23	22·69	8·27	3·1	..	..	4·64	94·2	..
	5	25·30	..	34·25	22·70	8·27	3·1	..	..	4·66	94·5	..
	0	25·28	..	34·23	22·69	8·27	3·1	..	..	4·65	94·4	..
H. 60	28	24·69	12	34·47	23·05	8·27	4·4	..	62	4·61	92·9	..
	20	24·68	..	34·48	23·06	8·27	4·4	..	82	4·67	94·1	..
	15	24·67	..	34·45	23·03	8·26	4·4	..	61	4·69	94·5	..
	10	24·68	..	34·44	23·03	8·27	3·5	..	72	4·70	94·8	..
	5	24·68	..	34·45	23·03	8·27	3·5	..	73	4·71	95·0	..
	0	24·68	..	34·44	23·03	8·27	3·5	..	72	4·70	94·8	..
H. 61	28	24·27	7	34·51	23·20	8·27	2·6	..	..	4·72	94·3	..
	20	24·17	..	34·48	23·21	8·27	2·6	..	..	4·73	94·6	..
	15	24·10	..	34·34	23·14	8·27	2·6	..	..	4·76	94·8	..
	10	24·09	..	34·37	23·18	8·27	2·6	..	..	4·77	95·1	..
	5	24·09	..	34·38	23·17	8·27	2·6	..	..	4·77	95·0	..
	0	24·09	..	34·36	23·15	8·27	2·6	..	..	4·76	94·9	..
H. 62	28	23·65	6·5	34·59	23·44	8·27	..	..	..	4·83	95·8	..
	20	23·64	..	34·59	23·47	8·27	..	..	..	4·81	95·3	..
	15	23·62	..	34·53	23·42	8·27	..	..	..	4·83	95·6	..
	10	23·63	..	34·53	23·42	8·26	..	..	..	4·83	95·7	..
	5	23·62	..	34·55	23·44	8·26	..	..	..	4·82	95·4	..
	0	23·63	..	34·55	23·44	8·26	..	..	..	4·84	95·8	..
H. 63	28	24·09	13	35·01	23·65	8·27	3·9	..	..	4·79	96·1	..
	20	24·09	..	34·97	23·62	8·27	3·9	..	..	4·80	96·1	..
	15	24·00	..	34·96	23·63	8·27	3·9	..	..	4·83	96·5	..
	10	23·99	..	34·93	23·63	8·27	3·5	..	..	4·83	96·6	..
	5	23·99	..	34·94	23·62	8·26	3·5	..	..	4·83	96·5	..
	0	24·00	..	34·93	23·61	8·27	3·5	..	..	4·84	96·7	..
H. 64	28	22·45	5·5	34·55	23·76	8·27	4·4	45	..	4·77	92·9	0·58
	20	22·46	..	34·58	23·78	8·27	4·4	..	..	4·77	92·8	0·58
	15	22·52	..	34·58	23·78	8·27	3·9	..	..	4·80	93·4	0·56
	10	22·55	..	34·55	23·73	8·27	3·9	..	..	4·76	92·7	0·49
	5	22·54	..	34·55	23·76	8·27	3·9	..	..	4·79	93·1	0·52
	0·5	22·53	..	34·55	23·76	8·27	3·9	38	..	4·79	93·3	0·56
H. 65	28	22·04	8	34·70	24·01	8·27	..	..	..	4·84	93·3	..
	20	22·07	..	34·70	23·99	8·27	..	..	..	4·85	93·5	..
	15	22·08	..	34·70	23·99	8·27	..	..	..	4·87	94·1	..
	10	22·10	..	34·70	23·99	8·27	..	..	..	4·87	94·0	..
	5	22·08	..	34·68	23·97	8·27	..	..	..	4·89	94·3	..
	0	22·04	..	34·59	23·93	8·27	..	..	..	4·88	94·1	..
H. 66	28	22·09	8	35·14	24·32	..	..	..	..	4·81	93·3	..
	20	22·05	..	35·18	24·35	..	..	..	..	4·83	93·9	..
	15	21·98	..	35·13	24·34	..	..	..	..	4·83	93·4	..
	10	21·91	..	35·10	24·34	..	..	..	..	4·83	93·2	..
	5	21·90	..	35·09	24·33	..	..	..	..	4·83	93·3	..
	0	21·90	..	35·09	24·33	..	..	..	..	4·84	93·3	..
H. 67	28	21·41	10	34·93	24·35	8·26	4·8	..	..	4·92	94·1	..
	20	21·41	..	34·93	24·35	8·27	4·8	..	..	4·97	95·0	..
	15	21·41	..	34·86	24·29	8·27	4·8	..	..	4·97	95·1	..
	10	21·41	..	34·85	24·28	8·27	4·8	..	..	4·95	94·7	..
	5	21·46	..	34·85	24·26	8·27	4·8	..	..	4·95	94·8	..
	0	21·81	..	34·85	24·17	8·27	4·8	..	..	4·94	95·0	..
H. 68	28	21·24	9	35·02	24·48	8·27	5·2	56	..	4·96	94·8	..
	20	21·27	..	34·98	24·42	8·27	5·2	..	..	4·97	95·1	..
	15	21·27	..	35·02	24·45	8·28	4·8	..	..	5·00	95·7	..
	10	21·27	..	35·02	24·45	8·28	4·8	..	..	4·98	95·3	..
	5	21·27	..	35·04	24·46	8·28	4·8	..	..	5·00	95·7	..
	0	21·26	..	35·01	24·44	8·27	4·8	24	..	5·00	95·5	..

TABLE II.—*Other Positions in the Barrier Reef Lagoon and Passages.*

Station.	Position.		Date.	Time.	Sounding (metres).	Sea.	Weather.	Remarks.
H. 1	About 1 mile N.N.W. of Low Isles	. .	25.vii.28	3.45 p.m.	14	Calm	Clear	. .
H. 2	E. of Low Isles	S. 16° 20′.9 E. 145° 36′.2	27.vii.28	12.45 ,,	30	Rippled to calm	,,	. .
H. 5	,, ,,	S. 16° 22′.1 E. 145° 35′.8	4.viii.28	11 a.m.	28·5	Calm	,,	Sea surface covered with *Trichodesmium.*
H. 8	Mouth of Daintree River	S. 16° 19′.8 E. 145° 28′.6	20.viii.28	10.5 ,,	14·5	Lumpy	Overcast	. .
H. 9	1 mile N.W. of Low Isles	. .	,,	11.20 ,,	15·5	Calm	,,	. .
H. 10	Near Satellite Reef	S. 16° 28′.2 E. 145° 38′.7	,,	1.45 p.m.	29	Lumpy	,,	. .
H. 12	Trinity Opening	S. 16° 30′ E. 145° 52′	24.viii.28	7.45 a.m.	45	,,	Clear	. .
H. 15	,,	S. 16° 24′ E. 145° 52′	6.ix.28	8 ,,	61	Rippled ; N.E. swell	,,	. .
H. 28	,,	S. 16° 24′ E. 145° 53′.5	19.xi.28	11 ,,	55	Rippled	,,	. .
H. 45	Three miles E. of S. Cape Bedford	S. 15° 16′ E. 144° 26′.5	26.ii.29	2.6 p.m.	31	Moderate	,,	. .
H. 46	S. of Lizard Island	S. 14° 44′ E. 145° 27′.5	27.ii.29	10.22 a.m.	31·5	Rippled	Overcast, rain	. .
H. 48	Inside Cook's Passage	S. 14° 32′ E. 145° 32′	28.ii.29	3.25 p.m.	31·5	Rippled to choppy	Ditto	Strong easterly drift
H. 49	1 mile S. of Two Islands	. .	1.iii.29	11.17 a.m.	31·5	Moderate	Ditto	. .
H. 51	In Papuan Pass	S. 15° 47′ E. 145° 47′	17.iii.29	11.5 ,,	45	Lumpy	Clear	. .

TABLE II.—*Hydrographical Observations.*

Station.	Depth (metres).	Temperature (° C.).	Secchi disc (metres).	S. ‰.	σ_t.	pH.	P. (mg. per m³).	Nitrate (mg. N_2 per m³).	Silicate (mg. per m³).	Oxygen (c.c. per l).	Oxygen saturation %.	Oxidizable organic matter (mg. per l.)
H. 1	12	22·00	6·5	34·72	24·02	..	..	..	..	..	..	..
	10	22·00	..	34·72	24·02	..	..	..	..	..	..	..
	5	21·98	..	34·72	24·02	..	..	..	..	..	..	..
	0	21·96	..	34·72	24·02	..	..	..	..	..	..	..
H. 2	25	22·40	6	..	..	..	..	..	..	..	..	..
	20	22·43	..	..	..	..	..	..	..	..	..	..
	15	21·95	..	..	..	..	..	..	..	..	..	..
	10	21·90	..	..	..	..	..	..	..	..	..	..
	5	21·96	..	..	..	..	..	..	..	..	..	..
	0	22·52	..	..	..	..	..	..	..	..	..	..
H. 5	20	21·70	7·5	34·84	24·20	..	..	..	..	..	..	..
	15	21·63	..	..	..	..	..	..	..	..	..	..
	10	21·60	..	34·76	24·17	..	..	..	..	..	..	..
	5	21·58	..	34·69	24·11	..	..	..	..	..	..	..
	0	21·77	..	34·73	24·09	..	..	..	..	..	..	..
H. 8	10	21·50	3·5	34·91	24·31	8·26	..	..	..	..	..	..
	5	21·50	..	34·92	24·31	8·24	..	..	..	..	..	..
	0	21·50	..	34·90	24·30	8·24	..	..	..	..	..	..
H. 9	10	21·40	6	34·91	24·34	8·24	..	..	..	..	..	..
	5	21·49	..	34·92	24·31	8·24	..	..	..	..	..	..
	0	21·54	..	34·90	24·30	8·24	..	..	..	..	..	..
H. 10	25	21·67	7·5	34·99	24·31	8·25	5·2	..	..	..	..	..
	20	21·68	..	34·99	24·31	8·25	5·2	..	..	..	..	..
	15	21·69	..	34·97	24·30	8·25	4·8	..	..	..	..	..
	10	21·79	..	34·99	24·29	8·25	4·8	..	..	..	..	..
	5	21·70	..	34·99	24·31	8·25	6·1	..	..	..	..	..
	0	21·77	..	34·99	24·29	8·26	5·7	..	..	..	..	..
H. 12	40	22·30	>30	35·18	24·30	8·26	3·9	..	..	4·70	91·6	0·48
	35	22·49	..	35·20	24·25	8·26	3·9	..	..	4·77	93·5	0·32
	30	23·14	..	35·20	24·08	8·26	3·5	..	..	4·68	92·4	0·23
	20	23·26	..	35·28	24·07	8·26	3·9	..	..	4·68	92·6	0·50
	15	23·22	..	35·31	24·13	8·26	3·9	..	..	..	..	0·43
	10	23·22	..	35·30	24·12	8·27	3·9	..	..	4·68	92·7	0·24
	5	23·21	..	35·28	24·10	8·27	3·9	..	..	4·60	91·1	0·43
	0	23·22	..	35·30	24·12	8·27	3·9	..	..	4·76	94·3	0·39
H. 15	55	23·66	23	35·26	23·95	8·27	4·4	..	..	4·65	92·7	..
	40	23·74	..	35·27	23·96	8·27	4·8	..	..	4·72	94·1	..
	30	23·82	..	35·23	23·89	8·27	4·4	..	..	4·73	94·4	..
	20	23·89	..	35·24	23·87	8·29	3·9	..	..	4·76	95·2	..
	15	23·90	..	35·24	23·87	8·29	3·9	..	..	4·74	94·8	..
	10	23·91	..	35·25	23·87	8·27	3·9	..	..	4·82	96·5	..
	5	23·92	..	35·26	23·89	8·27	3·9	..	..	4·82	96·5	..
	0	23·98	..	35·26	23·86	8·28	3·9	..	..	4·84	97·0	..
H. 28	50	26·40	11	35·23	23·10	8·27	4·4	..	..	4·42	92·2	..
	30	26·48	..	35·21	23·06	8·27	4·4	..	..	4·44	93·0	..
	20	26·55	..	35·18	23·01	8·27	4·4	..	..	4·52	94·8	..
	15	26·60	..	35·19	23·01	8·26	4·4	..	..	4·56	95·6	..
	10	26·61	..	35·17	23·00	8·26	4·4	..	..	4·55	95·4	..
	5	26·67	..	35·17	22·97	8·26	..	..	..	4·57	95·9	..
	0	26·98	..	35·16	22·85	8·26	3·1	..	..	4·58	96·5	..
H. 45	25	28·15	7	34·41	21·90	..	3·1	50	..	4·10	87·8	..
	20	28·32	..	34·28	21·78	..	3·5	..	..	4·10	88·0	..
	15	28·43	..	34·17	21·66	..	2·6	..	..	4·20	90·2	..
	10	28·81	..	34·05	21·44	..	2·2	50	..	4·36	94·2	..
	5	28·90	..	34·05	21·40	..	2·2	..	..	4·34	93·9	..
	0	28·91	..	34·05	21·40	..	2·2	..	..	4·30	93·1	..
H. 46	28	27·12	9	34·82	22·58	..	4·4	100	..	3·74	78·7	..
	20	27·52	..	34·66	..	..	..	..	..	4·13	..	..
	15	27·88	..	34·50	22·07	..	3·1	..	..	4·14	88·1	..
	10	27·97	..	34·44	22·00	..	3·1	..	..	4·20	88·4	..
	5	27·93	..	34·36	21·97	..	3·1	..	..	4·22	89·3	..
	0	27·87	..	34·24	21·88	..	3·1	50	..	4·18	88·9	..
H. 48	28	27·58	12	34·49	22·16	..	4·4	..	..	4·01	85·0	..
	20	27·56	..	34·41	22·10	..	3·5	..	..	4·32	91·3	..
	15	27·62	..	34·41	22·10	..	3·5	58	..	4·35	92·0	..
	10	27·61	..	34·39	22·09	..	3·5	..	..	4·38	92·6	..
	5	27·62	..	34·32	22·03	..	3·1	67	..	4·42	93·4	..
	0·5	27·60	..	34·12	21·89	..	3·1	..	..	4·35	92·0	..
H. 49	20	28·30	..	..	..	..	..	..	..	..	..	..
	10	28·62	..	..	..	..	..	..	..	..	..	..
	0·5	28·62	..	..	..	..	..	..	..	..	..	..
H. 51	40	28·20	14	34·60	22·05	8·26	4·4	..	..	4·02	86·2	..
	30	28·20	..	34·57	22·03	8·26	3·9	..	..	4·08	87·6	..
	20	28·22	..	34·54	22·01	8·26	3·9	..	..	4·19	90·0	..
	10	28·23	..	34·54	22·01	8·26	3·9	50	..	4·18	89·8	..
	5	28·31	..	34·56	21·98	8·26	3·9	43	..	4·18	89·8	..
	0	28·37	..	34·60	21·98	8·26	3·5	..	..	3·93	84·7	..

TABLE III.—*Positions Seaward of the Barrier Reef.*

Station.	Position.		Date.	Time.	Sounding (metres).	Sea.	Weather.	Remarks.
H. 22	A. Near 183 m. line. Outside Trinity Opening	..	20.x.28	9.45 a.m.	>230	Calm, S.E. swell	Clear	..
	B. Ditto	S. 16° 20′ E. 146° 3′	,,	10.20 ,,	225	Ditto	,,	..
H. 23	Outside Trinity Opening	S. 16° 19′ E. 146° 7′	20.x.28	3 p.m.	>600	,,	,,	..
H. 30	Outside Trinity Opening in about 838 m.	S. 16° 19′ E. 146° 5′	23.xi.28	12.4 to 1.33 p.m.	>600	Calm with swell	,,	Slight southerly drift.
H. 31	Linden Bank	S. 16° 17′ E. 146° 2′	24.xi.28	7.27 a.m.	34	Ditto	,,	
H. 47	Outside Cook's Passage	S. 14° 31′ E. 145° 35′	28.ii.29	9.50 ,,	Recorded about 915	,,	Overcast	Slight northerly drift.
H. 52	Deep outside Papuan Pass	S. 15° 45′.4 E. 145° 49′.1	18.iii.29	8.15 ,,	>732	Calm	Clear	Current running east.
H. 53	Near 183 m. line S. of Papuan Pass	S. 15° 46′.2 E. 145° 49′.7	18.iii.29	2 p.m.	*c.* 183	,,	,,	..

TABLE III.—*Hydrographical Observations.*

Station.	Depth (metres).	Temperature (° C.).	Secchi disc (metres).	S. °/₀₀.	σ_t.	pH.	P. (mg. per m³).	Nitrate (mg. N_2 per m³).	Silicate (mg. per m³).	Oxygen (c.c. per l).	Oxygen saturation %.	Oxidizable organic matter (mg. per l).
H. 22	A. 0	26·20	..	35·31	..	8·28	3·1	..	..	4·67	97·3	..
	B. 180	19·21	36	35·63	25·48	8·20	14·0	..	..	3·70	68·5	..
	100	22·50	..	35·62	24·57	8·24	7·4	..	..	3·83	75·2	..
	50	25·22	..	35·28	23·51	8·27	3·5	..	..	4·69	95·9	..
	20	25·97	..	35·29	23·27	8·28	3·1	..	..	4·63	96·1	..
	10	26·05	..	35·24	23·20	8·27	3·1	..	..	4·68	97·3	..
	5	26·10	..	35·22	23·19	8·28	3·1	..	..	4·64	96·5	..
	0	26·48	..	35·17	23·03	8·28	3·1	..	..	4·70	98·3	..
*H. 23	500	c. 12·03	..	34·80	26·46	8·17	18·4	..	..	4·06	65·8	..
	300	15·61	..	35·22	26·03	8·18	13·5	..	..	3·91	67·9	..
	100	23·98	..	35·56	24·09	8·25	6·6	..	..	4·21	84·7	..
	0	27·12	..	35·14	22·82	8·28	3·1	..	..	4·64	98·7	..
†H. 30	600	c. 10·9	40	34·55	c. 26·47	7·93	25·8	167	..	3·99	63·2	..
	400	12·04	..	34·96	26·57	8·01	20·8	150	..	3·96	64·3	..
	200	17·50	..	35·46	25·77	8·01	13·5	100	..	3·55	63·7	..
	100	23·20	..	35·77	24·48	8·19	10·5	40	..	3·43	68·2	..
	50	26·57	..	35·16	22·98	8·26	4·8	32	..	4·50	94·3	0·47
	25	26·81	..	35·13	22·90	8·26	2·6	..	..	4·47	93·9	0·46
	5	26·91	..	35·08	22·83	8·26	3·9	..	..	4·49	94·3	0·50
	0	27·40	..	35·11	22·70	8·26	3·9	0	..	4·46	94·7	0·20
H. 31	28	26·81	25	35·13	22·91	8·25	3·9	..	..	4·46	93·5	..
	20	26·83	..	35·12	22·89	8·25	4·4	..	..	4·49	94·1	..
	10	26·83	..	35·09	22·87	8·25	4·4	..	..	4·58	96·0	..
	5	26·88	..	35·10	22·85	8·25	4·4	..	..	4·67	98·1	..
	0	26·84	..	35·11	22·89	8·25	4·4	..	..	4·56	95·6	..
H. 47	595	9·5	14	34·54	26·70	..	34·9	..	..	4·18	64·4	..
	400	11·91	..	34·96	26·59	..	25·3	..	..	4·01	65·0	..
	200	20·43	..	35·68	25·19	..	12·7	..	..	3·70	70·1	..
	100	25·19	..	35·24	23·48	..	6·1	..	..	4·25	86·9	..
	50	27·57	..	34·58	22·23	..	5·7	..	..	4·16	86·1	
	25	27·97	..	34·60	22·11	..	4·8	46	..	4·27	91·2	..
	10	27·97	..	34·53	22·06	..	3·5	..	..	4·41	94·2	..
	5	27·94	..	34·54	22·10	..	3·5	22	..	4·26	90·8	..
	0	27·88	..	34·45	22·03	..	3·5	..	..	4·34	92·5	..
H. 52	400	11·78	28	35·05	26·68	8·04	27·5	..	..	3·96	64·1	..
	200	18·13	..	35·51	25·67	8·12	14·4	..	..	3·67	67·7	..
	100	25·33	..	35·35	23·54	8·25	7·2	..	..	4·34	88·9	..
	50	28·10	..	34·58	22·07	8·26	3·1	..	..	4·34	92·9	..
	20	28·22	..	34·57	22·03	8·26	3·9	28	..	4·33	93·0	..
	10	28·24	..	34·56	22·02	8·26	3·9	..	..	4·33	92·9	..
	5	28·30	..	34·58	22·00	8·26	3·9	..	..	4·34	93·3	..
	0	28·54	..	34·58	21·94	8·26	3·9	..	..	4·35	93·9	..
H. 53	100	23·67	..	35·52	24·14	8·21	9·3	100	..	4·02	80·3	..
	50	28·14	..	34·64	22·12	8·26	3·5	34	..	4·35	93·2	..

* Temperature at 500 m. not reliable. More than 20 minutes elapsed between closing bottle and reading temperature.

† 12 minutes between closing bottle and reading temperature at 600 m.

TABLE IV.—*Meteorological Observations at Low Isles.*

Date.	Air temperature.				Rainfall (inches).	Wind.		Sunshine.		Remarks.
	Maximum (° C.).	Minimum (° C.).	Dry bulb (° C.).	Wet bulb (° C.).		Direction.	Average m.p.h. for 24 hrs.	hrs.	mins.	
1928. July										
1	..	..	..	..	0	..	..	..		..
2	..	..	..	..	0·03	..	..	..		..
3	..	..	..	..	0·03	..	..	..		..
4	..	..	..	..	0·05	..	..	..		..
5	..	..	..	..	0·02	..	..	..		..
6	..	..	..	..	0	..	..	..		..
7	..	..	..	..	0	..	..	..		..
8	..	..	..	..	0	..	..	..		..
9	..	..	..	..	0	..	..	..		..
10	..	..	..	..	0·75	..	..	..		..
11	..	..	..	..	0·40	..	..	..		..
12	..	..	..	..	0·10	..	..	..		..
13	..	..	..	..	0·02	..	..	..		..
14	..	..	..	..	0·05	..	..	..		..
15	..	..	..	..	0·02	..	..	..		..
16	..	..	..	..	0	..	..	..		..
17	..	..	..	..	0	..	..	..		..
18	..	..	..	..	0	..	..	..		..
19	..	..	..	..	0	..	..	..		..
20	..	..	..	..	0	..	..	..		..
21	..	..	..	..	0	..	..	..		..
22	..	..	..	..	0	..	..	..		..
23	..	..	..	..	0·11	..	..	..		..
24	..	..	..	..	0	..	..	..		..
25	..	..	..	..	0	..	..	..		..
26	..	..	..	..	0	..	..	..		..
27	..	..	..	..	0	..	..	..		..
28	..	..	..	..	0	..	..	..		..
29	..	..	..	..	0	..	..	..		..
30	..	..	..	..	0	..	..	..		..
31	..	..	..	..	0	..	..	..		..
Aug.										
1	..	..	..	..	0	..	..	7	10	..
2	..	..	..	..	0	..	..	4	40	..
3	..	..	..	..	0	..	..	3	0	..
4	..	..	..	..	0·07	..	..	10	15	..
5	..	..	..	..	0	..	..	2	40	..
6	..	..	..	..	0	..	..	2	0	..
7	..	..	..	..	0	..	..	0	30	..
8	..	..	..	..	0	S.S.E.	..	9	50	..
9	..	..	..	..	0	S.S.E.	16·12	7	30	..
10	..	..	..	..	0·02	S.E.	16·80	8	0	..
11	..	..	..	..	0	S.E.	15·32	9	40	..
12	..	..	..	..	0	S.S.E.	14·72	4	15	..
13		..	..	..	0·02	S.E.	17·24	4	30	..
14	..	..	..	..	0·01	S.S.E.	17·09	1	30	..
15	..	..	..	..	0·01	S.E.	16·79	0	45	..
16	..	..	..	..	0	S.E.	15·56	10	30	..
17	..	..	..	..	0·07	S.S.E.	15·91	2	20	..
18	..	..	..	..	0·02	S.S.E.	13·61	5	30	..
19	..	..	..	..	0	S.S.E.	16·96	6	30	..
20	..	..	..	..	0	S.S.E.	17·37	2	45	..
21	..	..	..	..	0·23	S.S.E.	13·05	9	30	..
22	..	..	..	..	0	S.S.E.	12·68	11	0	..
23	..	..	..	..	0	S.S.W.	10·06	9	30	..
24	..	..	..	..	0	S.S.W.	9·33	10	30	..
25	..	..	..	..	0·01	S.	6·74	10	0	..
26	26·2	21·5	..	..	0	S.S.E.	8·54	11	0	..
27	28·1	21·0	23·0	21·4	0	S.S.E.	13·75	10	30	..
28	29·4	21·3	24·1	22·4	0	S.E.	13·75	10	0	..
29	27·5	21·6	23·2	21·5	0	S.E.	17·47	10	0	..
30	27·0	20·0	20·5	20·3	0·04	S.E.	19·14	4	40	..
31	28·2	20·3	23·9	22·0	0·12	S.S.E.	14·98	7	15	..

TABLE IV.—*Meteorological Observations at Low Isles* (continued).

Date.	Air temperature.				Rainfall (inches).	Wind.		Sunshine.		Remarks.
	Maximum (° C.).	Minimum (° C.).	Dry bulb (° C.).	Wet bulb (° C.).		Direction.	Average m.p.h. for 24 hrs.			
1928. Sept.								hrs.	mins.	
1	29·8	21·0	24·6	22·4	0	S.	12·68	11	0	..
2	31·2	19·0	23·8	21·8	0	W.S.W.	7·73	11	0	..
3	30·8	19·5	23·9	21·6	0	S.W.	2·06	11	0	..
4	29·3	19·8	24·2	22·2	0	S.S.W.	11·22	11	0	..
5	29·3	19·3	22·1	20·6	0	W.N.W.	3·68	10	30	Wind N. at 10.30 a.m.
6	30·0	19·5	24·4	23·2	0	S.	5·07	10	10	..
7	29·25	21·5	24·6	22·4	0	S.	10·27	9	30	..
8	30·7	21·7	25·0	22·9	0	S.	10·55	10	15	..
9	31·6	22·0	25·9	23·8	0	S.	..	8	30	..
10	31·6	22·0	26·1	24·0	0	S.	..	10	40	..
11	..	21·0	26·0	22·9	0	S.S.E.	5·72	10	0	..
12	31·5	..	..	..	0	S.S.E.	11·22	9	5	..
13	31·5	20·4	25·1	22·5	0·45	S.S.E.	11·22	10	30	..
14	30·3	20·8	25·5	23·3	0	S.E.	6·69	10	50	..
15	28·2	22·2	25·9	24·0	0·03	E.S.E.	14·68	8	0	..
16	29·3	21·5	24·5	21·8	0·10	S.S.E.	17·85	10	30	..
17	30·0	21·5	25·9	22·0	0	S.E.	12·57	10	15	..
18	30·6	21·3	25·5	22·5	0	S.	7·63	10	30	..
19	29·8	21·7	24·7	21·8	0	S.S.E.	6·75	10	30	..
20	31·1	22·0	26·2	22·8	0	S.	10·81	10	30	..
21	32·1	23·3	27·0	25·0	0	S.E.	11·35	10	0	..
22	33·2	23·5	27·7	24·2	0	S.E.	8·81	10	15	..
23	33·0	22·8	27·2	23·7	0	W.S.W.	3·82	11	5	..
24	33·3	23·0	28·0	24·8	0	S.E.	3·07	10	15	..
25	33·0	23·5	28·0	23·3	0	S.E.	13·88	3	0	..
26	33·3	23·5	28·7	25·0	0	E.S.E.	11·31	9	45	..
27	33·5	23·5	28·6	24·1	0	E.S.E.	5·99	10	45	..
28	33·5	23·1	26·0	22·4	0	S.E.	9·72	10	0	..
29	30·2	22·6	27·0	20·7	0·02	E.S.E.	17·24	10	10	..
30	31·6	22·1	26·3	21·4	0·01	S.E. .	19·12	10	0	..
Oct.										
1	31·2	22·1	26·9	21·8	0	S.S.E.	15·6	10	30	..
2	31·7	21·7	26·1	22·3	0	S.	10·22	11	10	..
3	32·6	22·3	27·5	23·3	0	W.S.W.	5·60	8	45	..
4	32·6	23·0	26·1	19·7	0	S.S.E.	7·20	6	50	..
5	32·4	22·9	26·8	22·5	0	S.S.E.	11·53	6	30	..
6	31·5	23·0	26·4	22·8	0	W.S.W.	5·49	6	30	..
7	32·1	22·0	26·6	22·9	0	W.	3·84	9	30	..
8	32·6	23·5	27·3	23·9	0	S.E.	4·51	10	30	..
9	34·7	23·8	29·4	24·7	0	E.S.E.	5·56	10	50	..
10	34·6	23·0	26·2	23·3	0	E.S.E.	6·71	9	0	..
11	32·1	23·0	26·7	24·1	0	E.S.E.	9·34	9	45	..
12	32·8	24·1	26·9	23·0	0	E.	14·66	9	45	..
13	33·2	23·9	29·3	24·2	0	E.S.E.	15·07	9	20	..
14	34·0	24·0	29·4	25·9	0	E.S.E.	14·11	7	45	..
15	33·8	23·6	29·3	24·2	0·01	E.	12·94	5	15	..
16	33·4	24·0	28·1	23·2	0	S.S.E.	11·46	10	20	..
17	34·0	23·3	26·1	22·5	0	S.E.	5·23	11	10	..
18	35·2	26·0	26·2	25·0	0·01	S.E.	8·34	11	10	..
19	34·2	24·2	28·6	23·9	0·07	E.N.E.	7·99	10	45	..
20	32·6	23·5	28·0	23·5	0	W.	3·89	10	0	..
21	32·4	23·6	27·0	23·4	0	W.N.W.	3·93	11	0	N.E. airs at 12.30 p.m.
22	33·2	23·5	28·4	22·9	0	W.N.W.	4·42	10	0	..
23	32·8	23·2	28·6	23·8	0	W.N.W.	4·89	10	10	..
24	32·0	23·8	27·9	23·8	0	W.N.W.	4·79	9	30	..
25	33·6	24·3	29·7	..	0	W.S.W.	4·46	9	25	..
26	35·1	24·1	28·0	24·2	0	E.S.E.	4·97	8	15	..
27	34·4	25·3	29·7	24·2	0	E.S.E.	6·21	9	45	..
28	34·0	26·0	28·6	24·7	0	S.E.	6·79	10	0	..
29	35·5	25·3	29·4	25·2	0	S.	7·25	8	15	..
30	35·8	27·5	29·7	26·1	0·01	S.E.	4·39	7	40	..
31	35·7	26·1	31·1	26·4	0	S.E.	6·59	7	20	..

TABLE IV.—*Meteorological Observations at Low Isles* (continued).

Date.	Air temperature.				Rainfall (inches).	Wind.		Sunshine.		Remarks.
	Maximum (° C.).	Minimum (° C.).	Dry bulb (° C.).	Wet bulb (° C.).		Direction.	Average m.p.h. for 24 hrs.	hrs.	mins.	
1928. Nov.										
1	32·2	21·8	25·8	23·2	1·31	W.	8·84	7	0	..
2	32·0	25·8	28·6	23·0	0·04	N.E.	6·71	9	30	..
3	34·5	25·2	30·5	25·0	0	E.	7·31	10	0	..
4	31·3	25·3	29·1	25·5	0	S.E.	8·02	2	0	..
5	32·5	26·8	28·0	26·1	1·09	W.S.W.	6·21	5	0	..
6	32·0	24·3	28·9	26·7	0·12	E.S.E.	4·71	4	30	..
7	34·6	25·1	28·6	25·5	0·01	S.E.	14·44	10	0	..
8	34·0	25·3	28·2	24·2	0·01	S.E.	9·87	7	30	..
9	30·2	22·8	27·8	25·0	0·32	S.E.	14·02	4	30	..
10	31·0	23·7	24·4	24·2	0·75	E.	15·62	3	15	..
11	28·2	21·7	27·0	23·5	1·15	E.S.E.	22·59	0	0	..
12	26·0	21·4	24·3	23·1	1·20	S.E.	22·80	0	0	..
13	28·0	22·1	24·4	23·1	0·45	S.S.E.	25·75	0	20	..
14	30·8	23·8	28·0	23·9	0·05	E.S.E.	21·24	2	5*	..
15	30·6	24·2	28·1	24·4	0·13	S.E.	17·44	9	20*	..
16	32·6	23·8	27·9	24·2	0	S.S.E.	14·33	10	40*	..
17	33·1	23·0	28·4	23·9	0	S.E.	9·00	10	30*	..
18	33·9	23·8	27·9	24·1	0	W.	3·79	9	10*	..
19	33·6	24·5	28·0	23·9	0	S.	5·93	9	20*	..
20	33·9	24·6	29·0	25·3	0	S.S.E.	5·95	8	45*	..
21	33·9	24·6	29·3	25·8	0	S.S.E.	5·27	9	15*	..
22	33·8	24·8	30·2	25·5	0	S.E.	7·13	7	30*	..
23	32·9	24·2	29·1	24·8	0	S.W.	4·16	8	0*	..
24	31·7	24·4	31·0	23·9	0	W.	3·52	8	0*	..
25	34·9	24·6	30·3	25·0	0	E.N.E.	3·34	8	0*	..
26	34·1	25·5	31·8	26·1	0	E.S.E.	7·00	7	45*	..
27	34·1	25·5	27·0	25·2	0	E.	4·47	6	30*	..
28	29·4	22·6	25·0	23·1	0·45	S.E.	9·34	0	45*	..
29	31·5	23·9	27·9	24·2	0·05	S.E.	14·64	6	45*	..
30	33·0	25·1	28·6	25·0	0	S.S.E.	12·99	6	10*	..
Dec.										
1	34·2	25·0	28·1	23·6	0	S.S.E.	11·71	7	20*	..
2	34·0	23·9	29·0	24·4	0	S.S.E.	7·13	7	0*	..
3	33·7	25·1	28·7	23·9	0	S.	8·04	7	0*	..
4	30·6	23·5	27·8	23·8	0	W.	3·76	6	45*	..
5	30·7	24·5	28·4	24·6	0	S.W.	3·64	6	15*	..
6	33·3	26·2	29·1	24·4	0	W.	7.11	6	0*	..
7	33·2	27·6	30·8	26·7	0	W.N.W.	7·61	6	15*	..
8	35·5	26·2	30·6	28·1	0	S.S.E.	7·96	6	0*	..
9	35·5	27·3	31·5	27·9	0	E.S.E.	6·13	6	0*	..
10	34·3	25·3	27·7	25·5	0·15	S.E.	11·64	5	50*	..
11	31·1	24·6	26·1	24·4	0·30	S.S.E.	13·50	..		..
12	31·7	23·4	26·8	25·6	0·82	S.S.E.	12·23	..		..
13	32·7	24·4	26·1	25·0	0·16	S.S.E.	15·87	6	0	..
14	..	25·2	27·8	25·8	0·18	S.S.E.	11·53	11	45	..
15	31·9	..	27·8	26·2	0·10	E.S.E.	11·09	8	0	..
16	31·0	24·9	25·7	25·1	0·08	S.S.E.	12·24	3	30	..
17	34·4	25·5	29·4	26·2	0	S.S.E.	11·51	11	20	..
18	34·4	26·2	30·0	26·1	0	S.S.E.	8·17	9	0	..
19	32·4	26·2	28·7	25·8	0	W.N.W.	3·92	7	0	..
20	33·7	26·6	29·4	25·9	0	W.N.W.	3·37	7	0	..
21	36·1	26·6	29·7	27·2	0	S.E.	2·94	10	45	..
22	36·2	27·1	30·3	26·7	0	W.	3·67	10	0	..
23	36·1	27·2	29·8	27·1	0	S.E.	4·55	10	15	..
24	34·4	26·7	30·1	26·7	0	W.N.W.	3·63	11	30	..
25	33·1	27·3	31·7	27·5	0	E.	3·69	8	30	..
26	33·9	26·9	29·1	26·6	1·02	W.	4·00	5	45	..
27	33·8	23·9	29·7	27·0	0·07	S.W.	4·09	7	20	..
28	33·3	24·4	29·4	27·1	0·09	S.E.	5·03	8	0	..
29	32·3	24·1	26·0	24·5	1·10	S.S.E.	14·84	4	15	..
30	32·9	24·7	28·9	25·5	0·20	S.E.	14·23	11	45	..
31	31·7	26·0	28·6	25·0	0	S.E.	14·39	10	30	..

* Record on this date not reliable since afternoon sun was lost.

TABLE IV.—*Meteorological Observations at Low Isles* (continued).

Date.	Air temperature.				Rainfall (inches).	Wind.		Sunshine.		Remarks.
	Maximum (° C.).	Minimum (° C.).	Dry bulb (° C.).	Wet bulb (° C.).		Direction.	Average m.p.h. for 24 hrs.			
1929. Jan.								hrs.	mins.	
1	31·0	26·2	29·4	25·1	0	S.S.E.	18·54	5	45	..
2	29·8	25·0	..	25·5	0·97	S.E.	22·50	0	0	..
3	30·8	24·0	26·7	25·5	1·97	S.S.E.	14·18	7	15	..
4	29·7	25·0	26·1	25·8	2·31	S.S.W.	9·08	0	0	..
5	32·2	25·0	29·6	27·8	0·25	E.N.E.	10·44	6	0	..
6	29·6	25·6	28·2	26·9	0·47	E.	10·18	1	30	..
7	32·3	25·3	26·7	25·8	0·55	E.S.E.	20·17	4	30	..
8	27·8	24·3	26·9	26·7	1·24	E.S.E.	22·47	0	0	..
9	28·1	25·6	25·8	25·3	2·05	S.E.	7·09	0	0	Light N.E. wind later.
10	30·2	24·9	26·9	25·4	0·65	W.	4·17	2	0	..
11	32·5	25·6	28·4	26·5	0·24	W.	4·41	5	30	Strong N. wind in afternoon.
12	31·9	25·5	26·1	25·6	0·21	W.	4·20	3	45	,, ,, ,,
13	34·4	24·5	28·4	26·0	0·47	S.E.	4·42	1	45	Light N. wind later.
14	34·7	26·2	27·6	25·2	0·04	W.	2·29	7	0	Northerly air in afternoon.
15	33·3	26·3	28·9	26·0	0	W.	7·29	7	30	..
16	33·2	26·9	29·9	26·8	0	W.N.W.	4·74	4	20	..
17	35·7	27·3	29·6	27·4	0	W.N.W.	3·52	4	10	Light N. in afternoon.
18	34·5	27·3	29·4	27·7	0·01	S.W.	2·22	4	0	..
19	34·5	27·5	29·6	27·6	0	W.	3·17	9	0	..
20	35·6	28·1	31·7	28·9	0	S.	2·86	9	20	..
21	33·1	26·5	28·8	26·9	0	E.S.E.	4·82	4	0	..
22	33·2	25·1	30·8	26·3	0·34	W.N.W.	8·70	7	30	..
23	33·9	24·9	28·2	26·1	0·82	W.N.W.	4·78	6	30	S.W. at 7.30 p.m.
24	34·9	26·4	28·4	26·8	0·07	W.	3·48	3	10	..
25	32·3	25·4	31·4	25·6	0·41	S.S.E.	6·19	8	15	..
26	33·4	24·4	28·8	25·0	0·06	S.S.E.	14·15	11	40	..
27	33·8	25·7	29·4	25·0	0	S.E.	9·63	11	40	..
28	34·4	25·6	29·1	25·0	0	W.	4·45	12	5	..
29	34·3	24·8	28·3	23·8	0	W.	4·63	11	30	..
30	33·1	25·6	29·7	24·4	0	S.E.	4·20	12	0	..
31	30·0	25·4	25·5	24·7	0·01	S.E.	7·78	0	0	..
Feb.										
1	33·8	25·2	29·4	26·3	0·72	S.E.	4·40	10	30	..
2	29·5	26·8	27·8	26·6	0·03	S.E.	8·61	0	10	..
3	26·6	23·9	24·4	24·1	5·44	E.S.E.	12·98	0	5	..
4	27·3	23·7	26·1	24·2	2·68	S.E.	13·88	0	15	Wind variable.
5	30·8	24·4	26·7	25·3	1·05	S.E.	15·03	1	15	..
6	31·2	24·9	25·1	25·0	0·60	E.S.E.	10·41	2	20	..
7	31·6	23·8	26·9	25·5	1·61	S.S.W.	8·55	5	15	..
8	31·6	24·7	25·6	25·1	0·15	S.	8·45	7	0	..
9	33·2	25·6	29·5	27·8	0·05	S.S.W.	3·89	11	45	..
10	33·9	25·9	27·9	26·1	0·00	W.	2·74	8	10	..
11	34·2	25·8	29·5	26·9	0·04	S.W.	2·16	11	30	Light N.E. during day.
12	34·4	26·8	31·7	26·9	0·00	E.	2·57	11	30	..
13	33·6	25·5	29·2	26·4	0·02	N.W.	1·80	7	30	..
14	34·8	26·4	30·3	26·7	0	W.	2·13	8	50	..
15	32·9	27·2	30·1	27·0	0	S.W.	2·79	4	30	Light N. in afternoon.
16	34·7	27·4	29·2	26·1	0	W.S.W.	2·87	6	10	Strong N. in afternoon.
17	35·2	27·1	30·8	26·3	0	W.	1·81	8	40	,, ,,
18	35·4	26·9	29·8	27·2	0·04	W.	2·12	11	30	..
19	35·2	27·0	29·7	26·4	0	W.N.W.	1·99	9	45	W. wind in afternoon.
20	32·7	27·0	27·8	26·1	0·02	N.N.W.	1·29	2	20	..
21	31·4	23·7	26·0	25·0	0·37	S.E.	5·55	5	0	..
22	33·9	25·8	28·9	26·1	0	W.N.W.	5·86	10	30	..
23	34·9	23·9	29·1	25·5	2·75	N.W.	2·97	9	10	..
24	26·6	24·4	25·7	25·0	0·52	S.	4·07	0	0	N.W. in afternoon.
25	28·5	23·6	..	23·9	2·81	S.W.	11·72	0	20	..
26	29·5	23·6	27·2	26·0	3·49	E.N.E.	22·03	1	5	Northerly swell in morning.
27	29·2	24·8	26·7	25·5	0·60	N.W.	11·37	2	15	..
28	30·7	23·6	24·4	23·7	1·10	N.W.	11·13	4	15	..

TABLE IV.—*Meteorological Observations at Low Isles* (continued).

Date.	Air temperature.				Rainfall (inches).	Wind.		Sunshine.		Remarks.
	Maximum (° C.).	Minimum (° C.).	Dry bulb (° C.).	Wet bulb (° C.).		Direction.	Average m.p.h. for 24 hrs.	hrs.	mins.	
1929. March.										
1	31·3	24·6	27·8	25·8	0·05	N.W.	2·57	2	20	..
2	32·4	25·6	27·8	25·6	0·08	N.W.	4·82	2	45	..
3	33·3	25·5	28·4	27·2	0·25	W.	4·76	10	15	..
4	33·9	26·6	30·0	26·9	0	W.	6·24	8	30	..
5	35·2	27·2	30·1	27·1	0	W.	4·06	11	30	..
6	35·1	27·4	30·4	27·6	0	W.	3·11	10	30	..
7	34·4	26·6	29·2	26·9	0	W.	4·80	11	30	..
8	32·5	..	..	..	0·56	S.	2·99	6	30	..
9	34·3	25·8	28·9	25·5	0·09	S.S.W.	6·65	9	15	..
10	30·6	25·0	28·6	25·8	0·08	S.S.W.	11·24	6	15	..
11	28·8	25·0	28·5	24·8	1·76	S.S.E.	17·93	0	45	..
12	28·6	25·0	26·4	25·4	1·47	S.E.	17·58	0	10	..
13	30·5	24·8	27·8	26·2	0·16	E.S.E.	16·75	5	0	..
14	30·7	25·4	28·9	26·6	0	E.S.E.	16·23	7	45	..
15	32·2	25·2	27·2	25·5	0	E.S.E.	..	7	30	..
16	31·9	25·8	28·7	25·0	0·21	S.S.E.	16·05	10	30	..
17	32·4	25·7	28·5	25·0	0	S.E.	10·91	10	45	..
18	31·7	24·5	27·2	24·8	0	W.	5·56	11	15	..
19	31·6	26·1	28·7	25·6	0	E.S.E.	5·39	10	45	..
20	31·9	24·9	29·4	24·6	0·06	E.S.E.	15·97	10	0	..
21	32·5	26·6	29·3	24·3	0	E.S.E.	19·79	10	0	..
22	31·5	25·0	27·5	24·8	0·05	S.S.E.	17·88	9	30	..
23	26·5	24·5	25·3	25·0	1·95	E.S.E.	15·82	0	5	..
24	29·6	23·1	26·0	24·6	2·70	S.E.	16·51	2	40	..
25	..	25·6	28·6	26·6	0·35	E.	10·92	9	30	..
26	32·3	25·8	26·7	25·5	0·08	S.E.	6·83	0	0	..
27	28·3	23·8	26·1	25·1	1·73	S.W.	5·61	2	30	N. at 3.30 p.m.
28	29·4	25·7	28·0	25·5	1·07	W.	2·96	7	0	N.W. at 6.30 p.m.
29	31·3	24·7	25·8	23·2	0·20	S.E.	12·30	2	10	..
30	28·6	25·0	25·5	23·8	0·06	S.E.	19·24	0	0	..
31	28·2	23·3	25·7	23·9	0·57	S.E.	12·14	1	15	..
April.										
1	27·2	23·7	25·3	23·9	1·09	S.S.W.	9·44	1	45	..
2	30·6	24·4	27·6	26·1	0·98	E.S.E.	4·00	5	20	N. wind at 5 p.m.
3	30·8	25·3	27·6	25·4	0·66	N.W.	3·23	2	45	,, at 5.30 p.m.
4	29·5	25·5	27·6	25·5	0·06	W.	3·98	6	0	Strong N. all day.
5	32·6	25·0	26·0	23·8	0·80	E.S.E.	10·44	0	35	..
6	28·3	21·6	25·8	25·0	0	S.E.	14·70	1	30	..
7	28·0	25·0	26·8	22·8	0	S.S.E.	14·53	9	45	..
8	29·6	24·0	25·9	21·1	0	S.S.E.	14·59	10	30	..
9	29·4	23·5	27·1	21·6	0	S.E.	14·15	10	20	..
10	30·1	24·0	26·5	22·3	0	S.E.	13·81	3	15	..
11	29·1	23·1	26·8	24·6	0·32	S.E.	14·31	7	45	..
12	29·9	23·4	26·5	23·4	0·21	S.E.	13·26	7	30	..
13	29·4	22·8	26·1	22·0	0·02	S.S.E.	13·36	10	25	..
14	29·9	26·1	26·2	22·4	0	S.E.	15·14	10	40	..
15	28·9	22·4	25·0	23·2	0·11	S.S.E.	18·22	4	20	..
16	27·6	22·8	26·1	22·6	0·09	S.S.E.	17·19	4	0	..
17	28·2	22·0	25·1	19·8	0·11	S.E.	17·94	10	10	..
18	27·3	22·8	24·3	20·9	0	S.E.	21·34	8	15	..
19	27·5	21·2	25·4	22·6	0·12	S.E.	18·10	10	35	..
20	27·6	22·8	25·0	25·0	0	S.E.	14·15	6	30	..
21	28·6	22·9	26·0	22·7	0	S.S.W.	9·50	10	10	..
22	30·3	22·7	26·0	22·9	0	S.W.	4·15	10	30	..
23	30·6	22·7	25·5	22·7	0	W.	3·72	9	40	..
24	31·2	23·4	26·6	23·8	0	S.W.	5·52	9	30	..
25	30·1	23·8	26·5	22·9	0	S.	8·34	10	0	..
26	30·2	22·2	24·7	20·5	0	S.W.	6·52	10	15	..
27	30·4	23·3	25·3	18·3	0	S.E.	10·46	10	0	..
28	26·7	21·2	23·9	17·5	0	S.S.E.	20·51	9	15	..
29	26·2	21·2	22·8	17·6	0	S.S.E.	15·60	9	15	..
30	27·3	21·2	24·5	19·6	0	S.E.	13·45	9	40	..

TABLE IV.—*Meteorological Observations at Low Isles* (continued).

Date.	Air temperature.				Rainfall (inches).	Wind.		Sunshine.		Remarks.
	Maximum (° C.).	Minimum (° C.).	Dry bulb (° C.).	Wet bulb (° C.).		Direction.	Average m.p.h. for 24 hrs.	hrs.	mins.	
1929 May.										
1	26·8	22·1	24·8	19·8	0	S.E.	13·95	10	10	..
2	29·9	22·2	25·2	21·4	0	S.S.E.	11·34	9	10	..
3	28·1	22·1	23·6	22·3	0·15	E.S.E.	16·75	3	20	..
4	27·8	22·3	25·8	22·0	0·07	E.S.E.	18·20	7	0	..
5	27·9	22·2	25·4	21·6	0·14	E.S.E.	18·06	9	30	..
6	29·3	21·8	25·1	21·7	0·04	S.S.E.	16·28	8	45	..
7	28·0	22·1	25·1	21·4	0·02	S.E.	14·82	8	30	..
8	27·9	22·8	24·8	21·1	0	S.	15·45	5	15	..
9	28·0	22·1	24·0	21·2	0·01	S.S.W.	13·87	0	10	..
10	26·5	22·7	24·5	20·9	0	S.	13·19	9	30	..
11	27·9	22·6	24·3	20·6	0	S.S.E.	16·68	9	45	..
12	28·1	22·9	23·8	21·7	0	S.	15·85	0	15	..
13	26·2	21·3	21·8	20·1	0·08	E.S.E.	17·79	7	15	..
14	27·3	21·5	24·8	22·8	0·21	E.S.E.	14·90	7	45	..
15	28·2	21·5	21·5	21·0	0·20	S.S.E.	16·65	0	45	..
16	25·1	21·4	23·9	21·1	0·14	S.	13·93	10	0	..
17	27·7	20·9	23·3	21·3	0	W.	8·84	10	0	..
18	28·4	21·2	24·2	21·8	0	W.	5·87	9	50	..
19	30·3	21·6	24·0	22·1	0	W.	4·89	9	35	..
20	28·6	22·2	24·4	21·8	0	S.	7·63	7	50	..
21	27·3	22·9	24·1	19·4	0	S.S.E.	17·66	8	30	..
22	27·5	22·0	23·8	20·3	0	S.W.	14·04	4	45	..
23	28·1	21·2	22·8	20·0	0	S.W.	9·43	6	15	..
24	27·1	21·9	23·4	18·5	0	S.S.E.	15·27	7	45	..
25	26·3	20·5	22·8	17·9	0	S.E.	11·23	8	20	..
26	27·7	19·1	21·9	18·4	0	S.W.	8·68	9	45	..
27	26·8	19·8	22·7	17·1	0	S.E.	7·34	10	0	..
28	26·4	19·7	23·1	17·8	0	S.S.E.	11·29	10	0	..
29	26·4	21·0	23·2	18·4	0	S.S.E.	13·20	10	0	..
30	26·7	20·6	23·8	20·4	0	S.S.E.	12·81	10	0	..
31	26·6	21·7	23·1	21·0	0	S.S.E.	14·10	6	45	..
June.										
1	27·3	21·2	24·5	21·9	0	S.E.	11·63	8	0	..
2	27·7	21·8	23·6	21·6	0	S.S.W.	10·35	7	10	..
3	28·1	22·4	26·0	21·6	0	E.S.E.	8·56	10	0	..
4	28·9	21·5	24·3	20·6	0	S.E.	9·60	9	15	..
5	27·8	20·8	23·3	21·7	0	S.	8·24	10	15	..
6	27·6	22·0	23·4	20·7	0	S.W.	6·58	10	0	..
7	27·8	20·8	22·0	21·6	0	S.E.	8·31	10	0	..
8	28·3	22·6	24·5	21·7	0	S.S.E.	12·39	6	45	..
9	27·4	21·8	22·6	19·2	0	S.E.	15·34	1	15	..
10	23·4	19·6	21·4	16·2	0	S.S.E.	20·53	9	50	..
11	24·1	19·7	21·2	14·7	0	S.S.E.	17·36	0	0	..
12	23·3	18·7	19·0	18·7	0·62	S.S.E.	17·46	0	0	..
13	20·4	18·9	19·4	18·3	1·00	S.E.	19·93	0	0	..
14	22·2	19·2	22·0	19·8	0	S.	19·66	2	45	..
15	25·6	18·2	20·8	17·2	0	S.W.	12·86	10	10	..
16	25·9	18·2	21·0	16·1	0	S.W.	5·65	10	20	..
17	25·7	18·7	20·5	18·0	0	W.	4·17	10	15	..
18	27·0	18·6	21·4	18·9	0	W.S.W.	3·98	10	5	..
19	27·3	18·9	23·3	20·3	0	S.	5·46	8	0	..
20	25·8	20·8	22·3	19·0	0	S.E.	14·23	8	30	..
21	25·6	19·9	21·4	18·6	0	S.S.E.	17·34	5	0	..
22	24·3	18·5	20·3	19·1	0·44	S.E.	14·17	5	0	..
23	23·2	19·0	20·4	19·1	0·20	S.S.E.	19·52	3	50	..
24	24·5	18·9	21·6	19·1	0·04	S.S.E.	15·41	4	20	..
25	24·8	20·1	22·4	19·0	0	S.S.E.	13·51	4	15	..
26	25·0	20·0	20·5	20·1	0	S.E.	14·99	1	30	..
27	23·3	20·5	21·8	19·6	0	S.E.	17·11	1	30	..
28	25·5	20·6	21·7	20·0	0	S.E.	9·63	6	10	..
29	27·6	20·3	22·9	21·0	0	S.S.W.	6·01	9	45	..
30	27·4	18·1	20·0	13·7	0	S.E.	9·61	10	15	..

TABLE IV.—*Meteorological Observations at Low Isles* (continued).

Date.	Air temperature.				Rainfall (inches).	Wind.		Sunshine.		Remarks.
	Maximum (° C.).	Minimum (° C.).	Dry bulb (° C.).	Wet bulb (° C.).		Direction.	Average m.p.h. for 24 hrs.			
1929. July.								hrs.	mins	
1	24·9	16·4	20·4	15·8	0	S.W.	7·64	10	10	..
2	25·6	18·6	22·5	19·0	0	S.E.	7·50	9	0	..
3	25·8	20·0	21·6	18·2	0	S.	13·65	3	15	..
4	24·4	18·8	21·2	19·9	0	S.E.	15·33	4	30	..
5	25·4	20·1	22·2	19·5	0·01	S.E.	12·44	5	0	..
6	25·5	19·7	22·5	19·0	0	S.E.	12·40	8	30	..
7	24·6	19·9	21·5	18·2	0	S.S.E.	19·21	5	0	..
8	23·8	19·2	20·9	18·4	0	S.	21·05	7	30	..
9	24·6	20·1	22·0	20·5	0	S.E.	14·90	9	30	..
10	25·7	19·3	21·6	20·0	0	S.S.W.	9·94	8	15	..
11	27·1	19·6	22·2	19·9	0	S.S.W.	7·96	9	45	..
12	27·3	19·8	23·8	21·1	0	S.S.W.	6·58	10	0	..
13	27·7	20·2	21·5	15·9	0	S.E.	12·11	9	30	..
14	23·8	18·5	20·0	16·2	0	S.E.	20·12	9	40	..
15	22·3	17·3	20·4	16·2	0	S.E.	18·53	10	0	..
16	23·8	17·2	..	..	0	..	(48 hours)	8	40	..
17	23·9	18·0	20·9	17·2	0	S.S.W.	15·16	9	45	..
18	26·1	17·4	20·1	18·2	0	S.S.W.	6·89	9	30	..
19	27·1	19·9	21·8	18·9	0	S.E.	11·71	4	50	..
20	24·6	18·4	19·8	16·5	0	S.S.E.	18·35	7	45	..
21	23·3	18·1	20·9	17·7	0	S.S.E.	16·71	7	30	..
22	25·1	19·1	20·0	19·4	0	S.S.E.	15·24	0	0	..

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INVESTIGATIONS

(*a*) VARIATIONS IN SOME PHYSICAL AND CHEMICAL CONDITIONS ON AND NEAR LOW ISLES REEF

(*b*) THE TEMPERATURE OF THE WATERS IN THE ANCHORAGE, LOW ISLES

(*c*) PHYSICAL AND CHEMICAL CONDITIONS IN MANGROVE SWAMPS

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WITH SEVEN TEXT-FIGURES AND ONE PLATE

(*a*) VARIATIONS IN SOME PHYSICAL AND CHEMICAL CONDITIONS ON AND NEAR LOW ISLES REEF

By A. P. Orr

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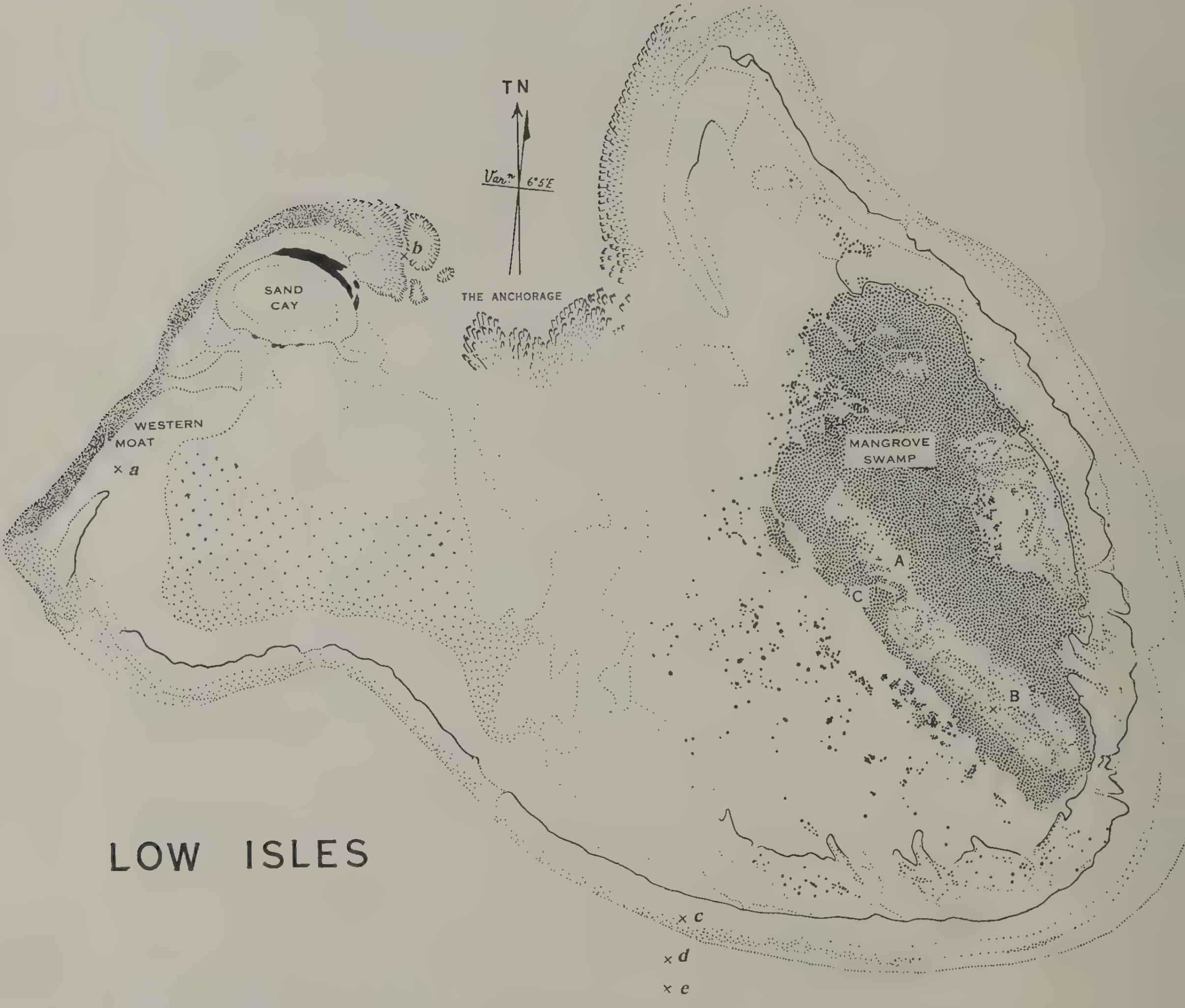
Although the conditions in the lagoon lying between the Barrier Reef and the mainland are remarkably uniform throughout the year except for temperature and salinity, the conditions on and in the immediate vicinity of coral reefs are very diverse. McClendon (1918) has made numerous observations on the oxygen content, pH value and carbon dioxide tension in the sea close to Loggerhead Key in the Tortugas. He found that there was a considerable diurnal variation; the water was usually supersaturated with oxygen during the day and under-saturated at night. The pH value and the carbon dioxide tension showed corresponding variations, the former rising and the latter falling during the day while the reverse was the case at night. Verwey (1930, 1931) has observed similar changes in oxygen content on the reefs in the Bay of Batavia.

A preliminary examination of the reef flat of Low Isles showed that like changes occurred there and were in some places much greater than had hitherto been recorded. They also indicated that the magnitude of the changes depended on the locality and on the state of the tide. The greatest changes occurred in coral pools isolated at low tide either during the night or during the day. Since such changes must be caused by, and must also influence, the inhabitants of the locality, it was considered best to make observations over 24 hours at certain selected positions.


TN
Varn 6°5'E
SAND CAY
b
THE ANCHORAGE
WESTERN MOAT
a
MANGROVE SWAMP
A
C
B
LOW ISLES
c
d
e

TEXT-FIG. 1.—Chart of Low Isles. Letters indicate the position of stations referred to in the text.

DIURNAL CHANGES.

Reef Flat.—As it was desirable to find the conditions among coral, a position was chosen on the reef flat in the Western Moat (Text-fig. 1, *a*). This was a coral pool with a sandy bottom, the minimum depth of which at low tide was 30 cm. It was connected over this part of the flat with many other coral pools. Except with a fresh wind blowing, however, the water in the pool was fairly well insulated. As the tide falls water is held up on the flat, and the level falls very slowly after the tide has partly receded. This fall of level continues, but at a greatly reduced rate, till the tide has turned and has risen far enough to flood the flat again. The amount of variation in the pool will depend, among other conditions, on the length of time the pool is isolated, and for this reason observations were made during springs, when the period of isolation is greatest. Since the pool was connected with many others, the results are probably true for this region of the reef flat at the date of the observations. In the pool coral easily outweighed all other organisms in importance, and the changes observed are to be attributed to it almost entirely. A description of the fauna and flora of this locality has been given by T. and A. Stephenson, Tandy and Spender in Vol. III, No. 2. Though the actual position worked at was not surveyed ecologically in detail, it did not differ in any important degree from the area a few yards away to be described later by Dr. Manton.

Table I.—*Position A on Reef Flat, 25th–26th November*, 1928.

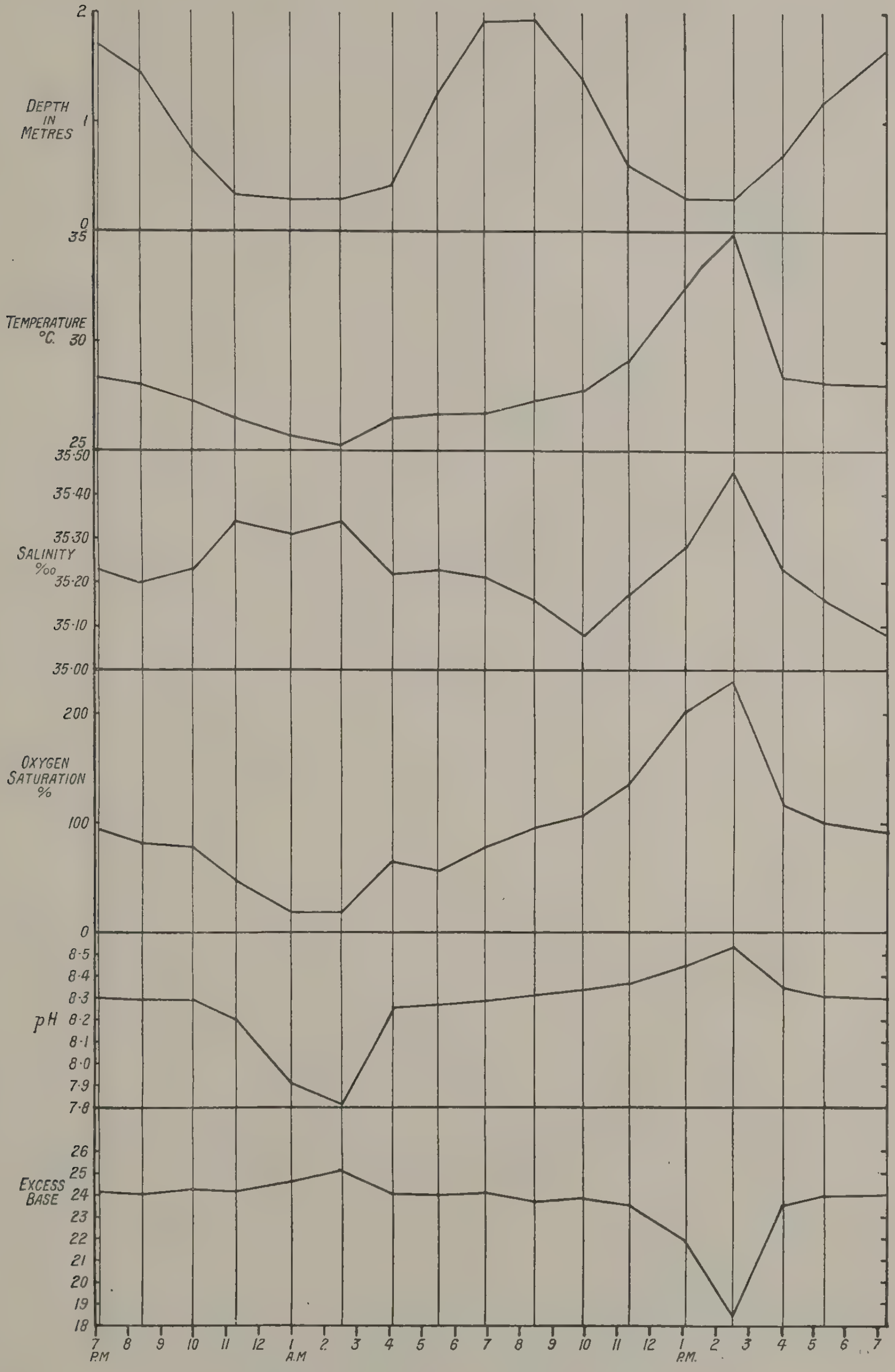
No.	Time.	Depth in cm.	Temperature (°C.)	Salinity °/∞.	O_2 c.c. per l.	O_2 saturation %.	P. mg. per c.m.	pH.	Excess base.
1	7.7 p.m.	170	28·30	35·23	4·35	94·2	2·6	8·30	24·13
2	8.26 ,,	146	28·02	35·20	3·76	80·9	2·6	8·29	24·02
3	9.58 ,,	74	27·29	35·23	3·61	76·7	3·1	8·29	24·23
4	11.22 ,,	34	26·48	35·34	2·24	47·0	3·5	8·20	24·13
5	1 a.m.	30	25·70	35·31	0·86	17·8	4·4	7·91	24·61
6	2.33 ,,	30	25·30	35·34	0·93	19·1	4·8	7·82	25·12
7	4.6 ,,	43	26·50	35·22	3·08	64·5	7·0	8·26	24·04
8	5.30 ,,	127	26·70	35·23	2·68	56·3	6·5	8·27	23·98
9	6.56 ,,	192	26·73	35·21	3·69	77·5	5·2	8·29	24·11
10	8.28 ,,	192	27·30	35·16	4·53	96·0	4·4	8·31	23·70
11	9.57 ,,	140	27·77	35·08	4·97	106·2	3·9	8·34	23·82
12	11.22 ,,	61	29·09	35·17	6·13	134·5	3·5	8·37	23·57
13	1.5 p.m.	31	c. 33 33·50 at 1.36 p.m.	35·28	8·44	200·9	3·1	8·45	21·93
14	2.32 ,,	30	34·90	35·45	9·45	230·4	4·8	8·53	18·50
15	4.3 ,,	69	28·40	35·23	5·40	117·1	3·9	8·35	23·57
16	5.31 ,,	119	28·13	35·16	4·68	100·9	4·4	8·31	23·92
17	7.15 ,,	165	28·01	35·08	4·30	92·5	4·4	8·30	23·98

A series of observations (Text-fig. 2 and Table I) were made in summer (25th–26th November, 1928) during calm weather and were begun at dusk. The samples were taken with the insulating water bottle every hour and a half from a position close to the bottom of the pool, irrespective of the height of the tide, so that the conditions beside the coral itself might be observed. Temperature, salinity, pH value, oxygen content and excess base were measured, the methods used being those described by Orr in Vol. II, No. 3, of these reports. As the tide fell at night and the pool became isolated, all the conditions examined showed changes. The temperature fell progressively till it reached air temperature (25·3° C.), and the salinity increased slightly owing to evaporation, but not enough to affect life in the pool. The consumption of oxygen by the animals and plants caused a fall in oxygen saturation, this fall being very steep after the pool became isolated at about 10 p.m. It reached the abnormally low value of 18% saturation (0·9 c.c. per l.) during the last hours of isolation (1–3 a.m.). This value is low enough to cause distress in fish at much lower temperatures (Krogh, 1916), and may account for the torpor often observed in fish on the reef flat at night. It is, however, not dangerously low for corals living on the reef flat, lasting as it does for at most a few hours (Yonge, Yonge and Nicholls, Vol. I, No. 8). Corresponding with this fall in oxygen, the pH value was considerably lowered, reaching a minimum of pH 7·82, and at the same time there was an increase in the total carbonates present as measured by excess base. The increased CO_2 tension will also have some effect on respiration. As soon as the rising tide replaced the water in the pool, there was an abrupt change towards open sea conditions. Salinity returned rapidly to its normal value and the temperature rose, as did also oxygen saturation and pH values. These remained comparatively constant again till the day fall in the tide began and the pool became isolated. Salinity then rose steadily, but again did not reach a very high value. The sun warmed the shallow water considerably, a maximum of 35° C. being reached just before the pool was again flooded. With the photosynthesis of the symbiotic algae causing oxygen production in excess of the requirements of the coral, the oxygen saturation value rose rapidly, reaching at the end of low tide the enormous value of 230% saturation (9·5 c.c. per l.). The pH value rose to 8·53, and there was also a considerable fall in the total carbonates present. As before, the influx of water with the rising tide in the evening brought about a rapid return to approximately open sea conditions.

During the night and the day low tides, the oxygen content of the water in the pool is far removed from equilibrium with the air. Even if the water is disturbed by wind, this inequality holds. It might be expected that in such conditions there would be a considerable gradient in oxygen in the pool with depth. Samples were taken under paraffin at 5, 15 and 25 cm. by means of a pipette and the oxygen content estimated. There were, however, no appreciable differences at these depths either by day or by night during low tide.

The above results probably represent about the maximum variations in oxygen content and pH value to be found on the reef flat of Low Isles in the course of the year. The observations coincided with a spring tide which would give a very long period of isolation for the pool. In addition the pool was isolated in the early afternoon, when the light was very bright, and at night when there was only moonlight. At neap tides the variations are not anything like so great, though they are still present, for the pool is then isolated, if at all, for a very short time, and the changes are distributed through a much greater volume of water.

A similar study of the same pool made about two months earlier (2nd October, 1928) gave results resembling those above (Table II). In this case, however, one low tide period occurred at dawn and the other at dusk. Very low values were not reached in oxygen saturation and pH value at the low tide at dawn, because a certain amount of photosynthesis was taking place in the early morning light. Similarly, in the evening at low



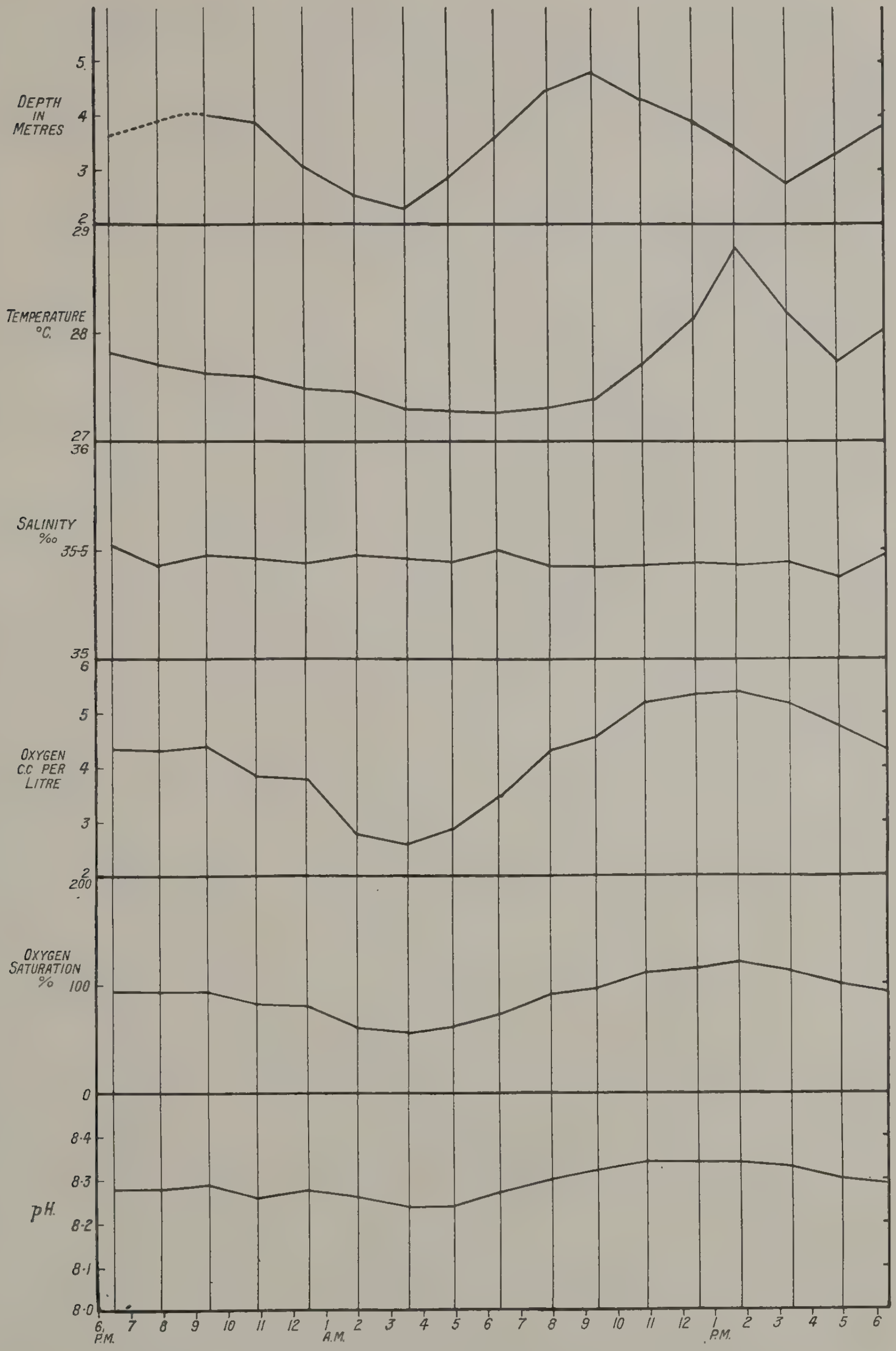
Text-fig. 2.—The diurnal changes at position *a* on the reef flat.

tide the light was too poor to allow much photosynthesis to go on, and only moderately high values for oxygen saturation and pH value were reached.

TABLE II.—*Position a on Reef Flat, 2nd October,* 1928.

No.	Time.	Depth in cm.	Temperature (° C.)	Salinity $^{\circ}/_{\circ\circ}$.	O_2 c.c. per l.	O_2 saturation %.	pH.
1	12.2 a.m.	105	25·2	35·38	4·10	83·7	c. 7·60
2	1 ,,	64	24·9	35·36	3·91	79·7	8·05
3	1.55 ,,	45	24·4	35·37	3·46	69·8	8·07
4	2.59 ,,	35	24·2	35·41	2·11	42·6	7·75
5	4 ,,	30·5	23·2	35·50	1·49	29·7	Acid to C.R.
6	5 ,,	30·5	22·7	35·46	1·52	29·8	7·75
7	6 ,,	28·5	22·5	35·51	4·23	86·0	Acid to C.R.
8	6.57 ,,	72	24·72	35·38	4·23	86·0	,, ,,
9	7.55 ,,	110	25·1	35·35	4·63	94·6	7·75
10	9 ,,	135	25·35	35·38	5·05	104·0	8·32
11	10 ,,	169	25·82	35·36	5·82	120·5	8·33
12	11 ,,	159	26·01	35·36	5·81	120·7	8·35
13	12 noon	131	26·45	35·36	5·74	120·3	8·35
14	1·5 p.m.	115	26·86	35·39	5·86	123·6	7·82(?)
15	2.5 ,,	79	27·47	35·39	6·22	132·6	8·38
16	3.5 ,,	48	28·12	35·39	6·81	146·8	8·45
17	4 ,,	38	28·55	35·48	6·96	151·3	8·45
18	5 ,,	34	27·70	35·57	6·42	137·7	8·42
19	6 ,,	60	26·20	35·43	4·84	101·1	8·28
20	7 ,,	88	25·60	35·40	4·44	91·6	8·26
21	8 ,,	114	25·60	35·37	4·27	88·1	8·25
22	9 ,,	140	25·70	35·39	4·39	90·4	8·26
23	10 ,,	134(?)	25·60	35·38	4·35	89·8	8·25
24	11 ,,	138	25·50	35·38	4·41	91·0	8·27

ANCHORAGE.—For comparison with the rather abnormal conditions which are found on the reef flat, a series of observations was made in the same way in the Anchorage (see Text-fig. 1, *b*). Here the effect of the tide will be much smaller, for there is no isolation from the open sea at any time. The position chosen was in a sandy patch between two large flourishing patches of coral. The coral here will be described by Dr. Manton. As before, samples were always taken at the same distance from the bottom, though a few additional samples were also taken near the surface. The observations were made in calm weather at the end of October, which is the beginning of the rainy season. The results are shown in Text-fig. 3 and Table III. As might be expected, the changes are much smaller here, but are still considerable. Temperature and salinity show little change, because of the much greater depth as compared with the reef flat. The oxygen saturation fell during the night, the minimum value reached being 56% at 3.30 a.m., while during the day it rose, the maximum (120%) being reached at 2 p.m. The changes in pH value are also correspondingly smaller, but they show the same tendency—a fall at night and a rise during the day. The results may be affected by the height of the tide to some extent, but it is more probable that the low night values and high day values for oxygen saturation and pH value do occur shortly before dawn and in the early afternoon respectively, quite independently of this.



TEXT-FIG. 3.—The diurnal changes at position *b* in the Anchorage.

TABLE III.—*At Position b in Anchorage, 29th–30th October*, 1928.

No.	Time.	Depth in cm.	Temperature (° C.)	Salinity ‰.	O_2 c.c. per l.	O_2 saturation %.	P mg. per c.m.	pH.
1	6.30 p.m.	. .	27·82	35·52	4·36	93·7	6·1	8·28
2	7.56 ,,	. .	27·71	35·43	4·31	92·5	4·4	8·28
3	9.25 ,,	400	27·63	35·48	4·38	93·8	3·9	8·29
4	10.54 ,,	388	27·60	35·46	3·84	82·2	3·9	8·26
5	12.28 a.m.	306	27·50	35·44	3·78	81·0	3·9	8·28
6	2.0 ,,	253	27·45	35·48	2·78	59·5	3·9	8·26
7	3.34 ,,	230	27·30	35·46	2·61	55·6	5·2	8·24
8	4.56 ,,	287	27·28	35·44	2·84	60·5	5·2	8·24
9	6.22 ,,	358	27·27	35·50	3·46	73·8	5·2	8·27
10	7.58 ,,	445	27·31	35·43	4·28	91·2	5·2	8·30
11	9.23 ,,	479	27·38	35·42	4·55	97·0	5·2	8·32
12	10·54 ,,	428	27·70	35·43	5·18	111·1	4·4	8·34
13	12.30 p.m.	389	28·12	35·44	5·34	115·3	4·4	8·34
14	1.49 ,,	342	28·77	35·43	5·38	120·5	4·4	8·34
15	3.24 ,,	274	28·17	35·44	5·18	112·1	4·4	8·33
16	4.55 ,,	327	27·73	35·37	4·72	100·1	4·8	8·30
17	6,23 ,,	377	28·02	35·47	4·30	92·7	4·4	8·29

A small gradient existed between bottom and surface samples, both during the day and during the night, but the changes occurring in the deeper water affected the whole of the supernatant water.

S.E. EDGE.—While changes occur on the reef flat and in the Anchorage to the north, the sea outside does not show such diurnal fluctuations. To find how far from the reef diurnal changes occur, three positions were examined to the S.E. of the reef on 15th and 18th June, 1929. These are shown in Text-fig. 1, *c*, *d* and *e*. *c* was on the boulder zone beyond the rampart, *d* was among growing coral, where the depth is about 3 metres, and *e* above a muddy bottom, where the depth is about 14 metres. Samples were taken both near the bottom and near the surface. Since the maximum changes are to be expected just before dawn and in the afternoon, the observations were made only at these times. The sea was calm when the observations were made. The results are shown in Tables IVA and IVB. At night, at the position *c* on the boulder zone the temperature was slightly lower than further off the reef, but the salinity showed no change. The oxygen saturation rose gradually from the shallow position on the boulder zone to *d*, where it was somewhat under normal sea value (slightly under-saturated), and from there to *e*, where it was practically the same as the open sea. There was no observable change in pH value. Surface and bottom samples did not differ appreciably. In the afternoon, inshore and surface samples had a slightly higher temperature, but again salinity was unaffected. The oxygen saturation on the boulder zone was high (119%), at *d* the water was still supersaturated (102%), the surface sample a little more so than the bottom sample, while at *e* the samples were not supersaturated and were the same at the surface and the bottom. The values at *e* were very close to those obtained at the station three miles east of Low Isles on the previous day. Changes in pH values followed those for oxygen. These results show that the changes occurring on a reef are strictly limited to the reef and, during calm weather, do not extend seaward beyond growing coral.

TABLE IVA.—*Conditions on the S.E. Edge of the Reef at* 5.30 *a.m.,* 17*th June,* 1929.

Position.	Depth in cm.	Depth of sample.	Temperature (° C.)	Salinity °/₀₀.	O_2 c.c. per l.	O_2 saturation %.	pH.
c.	74	Bottom	21·96	34·45	4·49	86·5	8·26
d.	284	,,	22·10	34·39	4·67	90·0	8·26
d.	284	100 cm.	22·04	34·47	4·66	89·8	8·26
e.	1788	747 ,,	22·18	34·41	4·82	93·2	8·26
e.	1788	100 ,,	22·14	34·45	4·82	93·1	8·26

TABLE IVB.—*Conditions on the S.E. Edge of the Reef at* 5 *p.m.,* 15*th June,* 1929.

Position.	Depth in cm.	Depth of sample.	Temperature (° C.)	Salinity °/₀₀.	O_2 c.c. per l.	O_2 saturation %.	pH.
c.	84	Bottom	22·88	34·32	6·11	119·3	8·33
d.	274	Bottom among growing coral	22·48	34·40	5·22	101·4	8·30
d.	274	100 cm.	22·60	34·44	5·31	103·3	8·30
e.	1417	Just off bottom	22·29	34·37	4·89	94·6	8·27
e.	1417	100 cm.	22·18	34·44	4·90	94·6	8·27

SEASONAL CHANGES.

While observations made over the diurnal range are instructive when we wish to know the changes at one position, it is impossible to make such series of observations frequently. For this reason, to find the changes in temperature, salinity, oxygen content and pH value, a number of observations were made at intervals in the course of the year at various positions.

TEMPERATURE.—The variation in temperature in the open sea is small when compared with that on the reef flat. It is unlikely that the temperature in the Anchorage or elsewhere in deep water near Low Isles ever reaches the lethal temperatures for corals. On the reef flat, however, temperatures were occasionally recorded which closely approached the lethal temperatures recorded by Mayer (1918). According to him the upper temperature limit for the common reef corals varies from 36° to 38° C. By means of a maximum thermometer, the highest temperature reached at the position *a* (Text-fig. 1) was measured during hot weather near the end of summer. The maximum reading obtained was 37·8° C. in a shallow sandy pool, and the maximum among growing coral 37·1° C. It is unlikely that the absolute maximum in a coral pool on Low Isles reef exceeds 40° C. On the sand, however, higher temperatures may be met with, and organisms living on the sand surface or on the beach rock must be capable of withstanding temperatures which may reach 50° C. The temperature in rock oysters living on the sand rock round the cay was greater than 44·8° C. on one occasion. It is worth noting, however, that Stanley Gardiner (1903, p. 177) has recorded temperatures up to 133° F. (56° C.) at low tide in pools rich in coral at Minikoi. This is considerably higher than the lethal limit for corals found by Mayer (1918), and yet according to Gardiner the corals in the pools suffered no ill-effect. The minimum temperature recorded in a coral pool during the cold weather on Low Isles was 18° C., though probably the absolute minimum is a few degrees lower. An exposure to temperatures of from 13° to 15° C. for five hours has been found lethal to common reef corals by Mayer (1918). No similar exposure is likely to have occurred on the reef flat of Low Isles during the year. Exposure to the air at low tide during hot weather is more likely to affect the corals than high or low sea temperature.

SALINITY.—Only during rainy weather are changes of salinity likely to affect the organisms on the reef. Normally the change in salinity caused by evaporation during low tide is small because of the high humidity (pp. 40–45 in Vol. II, No. 3, and Text-fig. 2). Even during the rainy season the salinity of water of the open sea is not lowered to near the lethal limits for corals as recorded by Mayer (1918). On the reef flat, during rainy weather, however, there may be considerable fluctuations. Much depends on the state of the tide at the time, for a heavy fall of rain occurring just when the flat is uncovering may reduce the salinity very considerably. If it occurs at high tide, however, the effect is minimized. Should the rain occur during a calm period, there is a possibility of the light, fresh layer remaining on the surface, to settle on the flat as the tide falls.

During the rainy season the flat was examined for salinity change at different places after any considerable fall of rain. The maximum lowering of salinity found was 50% (salinity 17·1°/$_{oo}$) ; this was in a pool 12 cm. deep on the flat, where there was very little growing coral. This lowering of salinity would be sufficient to affect the coral adversely if it lasted for long. Mayer (1918) has shown that a dilution of sea-water with an equal volume of rain-water does not affect the common reef corals unless it lasts for some time. In 4½ hours there was no injury, in 11½ hours about half of the species were killed, while in 24 hours nearly all were killed. The lowest salinity found in pools rich in coral was 27°/$_{oo}$, but as the corals would only be exposed to this for an hour or two, they are not likely to have been affected adversely. On one occasion the Daintree River, coming down in flood, swept out large quantities of silt, which reached as far as Low Isles. The lowering of salinity on the reef flat on this occasion was not exceptional. Such freshets, however, can and do destroy coral reefs, especially those near the shore. A reef at Bowen, further south, is known to have been destroyed in this way (Hedley, 1925). With a reef as far removed from the mainland and the mouth of a large river as Low Isles reef it would require an unusually heavy rainfall, perhaps accompanied by a freshet from the mainland to cause serious damage. Even then, since the lighter fresh water tends to remain on the surface, probably only the coral on the reef flat would be killed and the deeper coral unharmed.

OXYGEN CONTENT AND pH VALUE.—The samples for the estimation of oxygen content and pH value were all collected during the day, generally immediately after the tide left the flat and again immediately before it covered it. These showed invariably, as in coral pools, supersaturation of oxygen and high pH values during the low tide period. The degree of supersaturation varied very much with the locality. The highest value reached was 278% (10 c.c. per l.) in the Madrepore Moat, and it was there, also, that the lowest value was reached (zero). The Madrepore Moat is rich in coral, and this probably accounts for the very high value. The zero value was caused by a peculiar and infrequent circumstance. At the time it occurred, a blue-green alga (*Trichodesmium* sp.) was floating about in masses on the sea surface. At low tide a large quantity of this was deposited in the moat and along its edges. There it decomposed, rapidly colouring the water purple and causing a disagreeable smell. Small fish in obvious distress were jumping out of the water on to the shingle. Though the water had been supersaturated with oxygen just when the tide left the flat, it was completely denuded of oxygen before the tide re-entered. Only pools in which the blue-green alga was deposited in quantity and decomposing showed this absence of oxygen. On no other occasion was a value below saturation with respect to oxygen found during the day on the flat. The pH value generally followed the oxygen saturation value closely in its rise in the pools. An exception to this was found, however, in very shallow pools. In these the oxygen content might remain stationary or even fall slightly at the end of the low-tide period, though the pH value would continue to rise. This lack of agreement is probably because the oxygen comes into equilibrium with the air more readily than does the carbon dioxide. This tendency of oxygen to come into equilibrium with the air would be greater in shallow than in deep pools. The pH value on the flat during the day was never below open sea values. It occasionally rose as high as pH 8·8.

PHOSPHATE.—A few estimations of the soluble phosphate in the water on the reef flat were made. Although the sand was found to contain appreciable quantities, the water contained generally only as much as or even less than was present in the open sea (see Vol. II, No. 3). This occurred both in pools and in the moats. The explanation of this is that many corals remove soluble phosphate by night as well as by day, as is shown by Yonge and Nicholls in Vol. I, No. 6.

SEDIMENT.—The sedimentation on Low Isles reef and its relation to coral growth is described by Marshall and Orr in Vol. I, No. 5, of these reports.

The seasonal changes in temperature, salinity, oxygen saturation and pH value are very much affected by the tides. In general, temperatures are higher in summer and lower in winter on the reef flat than in the open sea, but the maxima depend very much on the depth of water on the flat when the sun is high and the minima on the relation of the night low tide to dawn. The salinity follows in general the same seasonal course as at the station three miles east of Low Isles (see Vol. II, No. 3), but on this is superimposed a small diurnal variation caused by evaporation (*cf.* Text-fig. 2), the amount of which depends on whether the tides are at springs or at neaps. During the rainy season, however, the salinity on the flat may fall to very low values. This depends almost entirely on the state of the tide. A heavy fall of rain at low tide will have the greatest effect. The seasonal changes in oxygen saturation and pH value in the sea are very small, and on the flat the diurnal changes mask them completely. No attempt was made to follow the seasonal changes in the Anchorage or on the S.E. of the reef, but it is obvious that these will correspond in temperature and salinity to the position three miles east of Low Isles with a small diurnal variation superimposed, while the diurnal changes in oxygen and pH value will again mask the small seasonal changes.

SUMMARY.

The changes in temperature, salinity, oxygen content and pH value on and near Low Isles Reef are described. These are, at times, large, and may have an important effect on the organisms on the reef. Tidal and diurnal changes are, on the whole, more important than seasonal changes.

Considerable help in this work was given by Mr. F. W. Moorhouse and several others, to whom I wish to express my thanks.

REFERENCES.

GARDINER, J. STANLEY. 1903. The Fauna and Geography of the Maldive and Laccadive Archipelagoes, I, pp. i–ix, 1–471, pls. i–xxv, text illust. Cambridge.

HEDLEY, C. 1925. The Natural Destruction of a Coral Reef. Trans. Roy. Geogr. Soc. Aust. (Queensland). Reports of the Great Barrier Reef Committee, I, pp. 35–40, pl. v, text illust.

KROGH, A. 1916. The Respiratory Exchange of Animals and Man. Monographs on Biochemistry, 173 pp., text illust. London.

MCCLENDON, J. F. 1918. On Changes in the Sea and their Relation to Organisms. Pap. Dept. Mar. Biol. Carn. Instn. XII, pp. 213–258, text illust.

MAYER, A. G. 1918. Ecology of the Murray Island Coral Reef. Pap. Dept. Mar. Biol. Carn. Instn. IX, pp. 1–48, pls. 1–19, text illust.

VERWEY, J. 1930. Depth of Coral Reefs and Penetration of Light. With Notes on Oxygen Consumption of Corals. Proc. Fourth Pacif. Sci. Cong. Batavia-Bandoeng (Java), IIA, pp. 271–294, text illust.

— 1931. Coral Reef Studies II. The Depth of Coral Reefs in Relation to their Oxygen Consumption and the Penetration of Light in the Water. Treubia, XIII, pp. 169–198, text illust.

(b) THE TEMPERATURE OF THE WATERS IN THE ANCHORAGE, LOW ISLES

By F. W. MOORHOUSE

From 7th August, 1928, to 21st July, 1929, the temperature of the waters in the anchorage at Low Isles was taken in the morning and again in the evening, both at the surface and at a depth of 1 metre.

At low water the Anchorage is a small bay open to the sea at the north and bounded by the shingle spit on the east, the reef flat on the south and the sand cay and projecting reefs on the west (see Text-fig. 1 and map of Low Isles in Vol. III, No. 2, Plate I). At half tide the reef flat is covered and the bay becomes a strait separating the mangrove island and the sand cay. Owing to the southerly extension of the mangroves, some slight protection from the south-east seas is afforded the Anchorage, but there is no barrier to the seas from the north and north-east, which are driven in by winds from these quarters at irregular intervals from October to early March.

The position where the temperature readings were taken was marked by a buoy. At no state of the tide was there less than one fathom of water at this spot.

From the temperature readings shown in Table V it will be seen that the lowest surface temperature was 20·25° C., recorded on the morning of 21st July, 1929, and the lowest temperature at a depth of 1 metre, 20·28° C. on 18th July. The highest recorded temperature was taken on the afternoon of February 12th, when the mercury in the thermometer rose above the scale to about 33·0° C. For several days prior to this the sky had been cloudless and there had been a light breeze from the north.

A Petersen-Nansen water-bottle was normally used for these temperature readings. When this was in use away from the island a Negretti & Zambra surface water thermometer was substituted.

TABLE V.—*Temperatures of Water at "Luana" Anchorage, Low Isles, Great Barrier Reef; Depth of Water never less than 1 Fathom.*

Date.	Surface.		1 metre.	
	9 a.m.	5.30 p.m.	9 a.m.	5.30 p.m.
Aug. 7	21·20	21·50	21·00	21·50
8	20·75	21·60	20·68	21·62
9	21·40	21·58	21·38	21·62
10	21·60	21·85	21·58	21·90
11	21·76	22·68	21·82	22·62
12	21·72	21·92	21·80	22·00
13	21·86	21·72	21·90	21·68
14	21·50	21·50	21·52	21·52
15	21·60	21·90	21·56	22·00
16	21·18	22·20	21·15	22·20
17	21·12	21·82	20·98	21·82
18	21·30	22·30	21·34	22·18
19	20·85	23·00	20·68	23·12
20	20·98	22·52	20·96	22·56
21	20·85	22·90	20·88	22·85
22	21·20	23·72	21·20	23·38
23	20·92	22·24	20·94	22·20
24	21·64	22·30	21·60	22·28
25	22·40	22·60	22·18	22·58
26	22·38	23·20	22·38	23·00
27	22·80	23·10	22·84	23·10
28	23·05	23·10	23·10	23·18
29	23·16	23·15	23·20	23·18
30	22·40	22·90	22·44	22·94
31	22·60	22·78	22·62	22·78
Sept. 1	22·45	22·95	22·45	22·78
2	22·78	27·12	22·72	23·35
3	22·70	24·95	22·68	23·85
4	22·95	26·70	22·78	24·92
5	23·02	23·62	23·10	23·62
6	23·54	24·92	23·40	24·76
7	22·74	24·48	22·72	24·40
8	24·20	23·92	24·12	23·95
9	23·88	23·98	23·88	23·98
10	24·20	24·00	24·30	24·00
11	24·00	24·20	23·90	24·18
12	23·90	24·28	23·90	24·30
13	24·38	24·45	24·40	24·40
14	24·36	24·76	24·40	24·80
15	24·40	24·90	24·42	24·92
16	23·58	24·90	23·78	24·70
17	24·16	24·52	24·20	24·55
18	24·28	25·50	24·28	25·40
19	24·34	25·08	24·40	25·08
20	24·34	25·28	24·14	25·30
21	24·10	25·16	24·10	25·16
22	25·20	25·20	25·20	25·18
23	25·40	26·10	25·44	26·12
24	26·18	25·16	26·26	25·12
25	25·30	25·20	25·42	25·18
26	25·41	25·41	25·54	25·40
27	25·70	26·06	25·76	26·10
28	25·40	25·50	25·44	25·50
29	25·35	25·42	25·40	25·46
30	25·00	25·36	25·06	25·38
Oct. 1	25·14	25·48	25·20	25·52
2	25·35	28·75	25·30	28·14
3	25·22	27·20	25·30	27·10
Oct. 4	25·22	25·38	25·30	25·35
5	25·15	25·60	25·04	25·64
6	25·88	25·90	25·54	25·85
7	26·42	25·85	25·94	25·50
8	26·44	25·75	26·42	25·78
9	26·90	26·60	26·96	26·55
10	25·98	26·10	26·05	26·08
11	26·12	26·10	26·16	26·08
12	25·90	26·10	25·92	26·08
13	26·00	26·18	26·04	26·20
14	25·94	26·40	26·02	26·40
15	26·18	26·48	26·20	26·50
16	26·02	26·76	25·96	26·38
17	26·35	26·84	26·36	26·48
18	26·55	27·32	26·50	27·20
19	26·74	27·50	26·70	27·46
20	27·20	27·50	..	..
21	27·00	28·08	27·00	28·08
22	27·30	26·80	27·16	26·80
23	27·64	26·70	27·64	26·70
24	26·64	26·70	26·60	26·70
25	26·72	26·95	26·75	26·90
26	26·84	27·20	26·86	27·18
27	27·18	27·82	27·22	27·82
28	26·80	27·10	26·80	27·10
29	27·35	27·72	27·32	27·80
30	27·42	28·82	27·40	27·69
31	27·54	30·02	27·50	27·94
Nov. 1	27·26	29·10	27·28	27·92
2	27·56	28·08	27·56	28·10
3	27·84	27·88	27·48	27·85
4	27·32	27·50	27·30	27·54
5	28·96	27·42	28·38	27·42
6	27·84	27·90	27·89	27·92
7	27·96	28·38	28·00	28·38
8	27·79	27·60	27·81	27·60
9	27·91	27·42	27·99	27·40
10	27·02	27·22	27·06	27·20
11	27·06	26·30	27·10	26·32
12	26·56	26·16	26·56	26·20
13	26·46	26·50	26·50	26·50
14	26·42	26·38	26·45	26·40
15	26·50	26·48	26·50	26·48
16	26·30	28·40	26·19	28·00
17	26·56	27·00	26·60	27·00
18	26·74	27·12	26·70	27·12
19	26·69	27·42	26·69	27·42
20	26·72	27·20	26·80	27·22
21	27·44	27·38	27·48	27·40
22	27·20	27·90	27·22	27·84
23	27·62	27·90	..	..
24	27·78	27·60	..	..
25	27·20	27·78	27·20	27·75
26	27·54	28·22	27·51	28·22
27	27·58	28·10	27·52	28·06
28	27·08	27·60	27·08	27·65
29	27·48	28·45	27·52	28·52
30	27·42	27·82	27·42	27·86

TABLE V—*continued.*

Date.	Surface.		1 metre.	
	9 a.m.	5.30 p.m.	9 a.m.	5.30 p.m.
Dec. 1	27·40	28·82	27·38	28·82
2	27·39	28·88	27·42	28·92
3	27·20	29·20	26·78	28·92
4	27·68	28·28	27·82	28·30
5	27·92	27·70	27·85	27·74
6	27·70	27·96	27·74	27·90
7	27·92	28·42	27·90	28·40
8	28·30	28·98	28·28	28·84
9	28·34	29·20	28·32	28·96
10	28·25	28·42	28·28	28·46
11	27·94	28·30	28·00	28·35
12	27·90	29·65	27·94	29·56
13	27·92	28·20	27·98	28·22
14	28·15	28·90	28·20	28·94
15	28·12	29·50	28·15	28·75
16	28·00	29·40	28·00	29·40
17	28·10	30·38	28·10	29·50
18	28·42	29·30	28·30	29·30
19	28·80	29·15	28·80	29·16
20	28·95	28·52	28·70	28·64
21	28·45	29·20	28·40	28·90
22	29·18	29·10	29·10	28·80
23	29·50	29·78	29·50	29·70
24	29·80	30·70	29·60	30·68
25	29·64	30·00	29·59	30·00
26	29·43	29·04	29·24	28·98
27	29·90	30·10	29·78	30·00
28	28·90	28·90	28·93	28·90
29	28·72	29·55	28·74	29·45
30	28·85	30·05	28·90	30·00
31	28·70	29·54	28·74	29·51
Jan. 1	28·30	28·70	27·80	28·70
2	28·10	28·50	28·12	28·50
3	28·09	29·00	27·98	29·00
4	28·20	28·70	28·22	28·72
5	28·20	28·92	28·20	28·92
6	28·30	28·00	28·35	28·00
7	28·18	28·78	28·20	28·60
8	28·10	27·75	..	28·15
9	28·10	28·00	28·10	28·00
10	27·34	28·00	27·70	28·08
11	27·56	28·65	28·16	28·60
12	28·18	29·98	28·20	30·02
13	28·35	29·62	28·35	29·62
14	28·18	30·84	28·18	30·40
15	28·14	30·47	28·18	30·47
16	28·75	29·75	28·64	29·75
17	28·64	30·95	28·64	30·84
18	29·28	30·32	29·24	29·35
19	29·08	31·98	29·00	31·70
20	29·71	30·24	29·62	30·20
21	29·21	29·90	29·25	29·90
22	29·68	31·54	29·68	31·18
23	29·28	29·80	29·30	29·80
24	29·38	29·90	29·40	29·80
25	29·05	29·46	29·10	29·46
26	29·04	29·50	29·00	29·55
27	29·00	31·10	29·00	29·45
28	29·14	31·20	29·10	31·20
Jan. 29	29·20	30·78	29·18	30·85
30	29·15	29·60	29·10	29·60
31	28·72	28·68	28·48	28·65
Feb. 1	28·82	29·62	28·86	29·68
2	28·95	28·48	28·60	29·00
3	28·48	28·15	28·55	28·30
4	27·70	28·28	28·25	28·28
5	28·35	29·00	28·38	28·50
6	28·30	28·40	28·32	28·40
7	28·35	29·05	28·35	28·95
8	28·18	28·98	28·20	28·65
9	28·55	31·00	28·25	28·92
10	28·52	30·38	28·60	29·06
11	28·98	32·50	28·94	29·24
12	29·44	33·00	29·18	29·98
13	30·30	32·45	30·08	32·45
14	29·88	31·30	29·20	31·12
15	29·62	30·94	28·80	31·05
16	29·20	29·42	29·16	29·42
17	29·08	29·48	29·20	29·44
18	29·76	30·12	29·70	29·68
19	29·70	30·36	29·72	30·36
20	29·56	30·02	29·56	29·68
21	29·05	29·72	29·05	29·52
22	29·38	30·28	29·31	30·14
23	28·92	29·72	28·85	29·60
24	29·00	29·40	29·00	..
25	28·20	28·00	..	..
26	28·00	29·60	..	..
27	28·20	29·00	..	..
28	28·10	29·00	..	..
Mar. 1	27·40	28·30	..	..
2	28·00	28·50	..	..
3	28·70	29·40	..	..
4	28·70	29·90	28·58	29·90
5	28·90	29·68	28·70	29·68
6	29·40	29·32	29·30	29·19
7	29·49	30·40	29·19	30·20
8	29·58	..	29·59	..
9	29·42	29·66	29·42	29·62
10	29·18	29·08	29·21	29·11
11	28·82	28·89	28·85	28·90
12	28·40	28·40	..	28·42
13	28·20	28·42	28·28	29·68
14	28·43	28·38	28·40	28·32
15	28·08	30·14	28·10	29·88
16	27·80	29·92	27·80	29·85
17	29·20	30·20	..	..
18	28·00	28·90	..	..
19	28·20	28·60	..	28·60
20	28·02	28·40	28·06	28·38
21	27·80	27·60	..	..
22	27·98	28·20	27·98	28·20
23	27·85	27·72	27·85	27·88
24	27·75	27·78	27·82	27·85
25	27·75	28·40	27·78	28·38
26	27·60	27·74	27·62	27·78
27	27·52	27·84	27·78	27·92
28	27·45	27·76	27·42	27·70

TABLE V—*continued.*

Date.	Surface.		1 metre.	
	9 a.m.	5.30 p.m.	9 a.m.	5.30 p.m.
Mar. 29	27·20	27·48	27·26	27·52
30	27·30	26·60	27·35	26·78
31	27·38	28·40	27·44	27·38
April 1	27·44	29·02	27·48	29·06
2	27·68	29·98	27·76	28·20
3	27·68	27·90	27·66	27·90
4	27·63	27·83	27·64	27·88
5	27·48	27·55	27·42	27·50
6	27·32	27·60	27·30	27·60
7	27·30	27·55	27·30	27·55
8	27·20	27·24	27·18	27·30
9	27·05	27·25	27·05	27·30
10	26·80	26·85	26·95	26·90
11	26·70	27·80	26·75	..
12	26·64	27·70	26·68	..
13	26·42	28·00	26·24	28·00
14	26·14	27·55	26·14	27·55
15	26·24	26·55	26·40	26·50
16	26·40	26·10	26·42	26·10
17	25·95	25·95	26·10	25·95
18	25·70	26·00	..	..
19	26·00	27·20	..	..
20	25·70	26·50	..	..
21	25·60	26·50	..	..
22	26·20	27·40	..	..
23	26·10	27·70	..	..
24	26·70	..	..	..
25	26·20	26·50	..	..
26	26·20	26·40	..	..
27	25·50	25·50	..	..
28	25·20	25·30	..	..
29	25·00	25·00	..	..
30	25·60	26·00	..	..
May 1	24·50	26·20	..	..
2	25·00	25·70	..	..
3	25·00	25·20	..	..
4	25·20	24·30	..	..
5	24·90	25·50	..	..
6	25·00	25·40	..	..
7	24·80	25·40	..	..
8	25·02	25·07	25·00	25·08
9	24·90	24·88	24·88	24·89
10	24·71	25·71	24·71	25·80
11	24·40	25·70	24·32	25·72
12	24·14	24·91	24·02	24·98
13	23·79	25·47	23·79	25·46
14	24·03	25·00	24·02	25·01
15	24·19	24·59	24·22	24·59
16	24·30	24·78	24·30	24·78
17	24·41	25·13	24·40	25·13
18	24·58	25·06	24·58	24·97
19	24·52	24·68	24·50	24·70
20	24·45	24·40	24·45	24·42
21	24·17	24·48	24·20	24·48
22	24·23	24·54	24·25	24·54
23	24·15	24·40	23·98	24·42
24	23·98	24·14	23·96	24·20
25	23·56	24·24	23·29	24·36
May 26	23·50	23·32	23·51	23·36
27	23·24	23·91	23·20	23·60
28	22·92	23·94	22·92	23·90
29	22·68	23·62	22·72	23·68
30	22·98	24·74	23·08	24·76
31	23·32	24·75	23·34	24·52
June 1	23·00	24·68	23·02	24·24
2	23·72	24·72	23·74	24·48
3	23·32	24·12	23·36	24·08
4	23·48	23·78	23·52	23·90
5	23·65	23·91	23·62	24·55
6	23·44	24·10	23·42	24·11
7	23·74	24·36	23·80	24·24
8	23·74	24·22	23·78	24·10
9	23·35	22·68	..	22·75
10	22·18	23·45	22·10	23·50
11	22·02	22·52	22·10	22·50
12	22·18	22·25	22·25	22·32
13	21·88	22·20	21·95	22·20
14	22·48	22·65	22·50	22·68
15	22·18	24·44	22·18	23·58
16	22·04	22·20	22·08	22·18
17	22·00	22·60	21·88	22·60
18	22·25	22·86	22·28	22·70
19	22·46	22·38	22·46	22·52
20	22·40	22·40	22·45	22·42
21	21·80	22·10	21·80	22·08
22	21·38	21·80	21·40	21·78
23	21·70	21·80	21·82	21·82
24	21·54	22·25	21·58	22·25
25	21·32	22·18	21·32	22·18
26	21·50	22·20	21·52	22·10
27	21·32	22·50	21·35	22·48
28	21·48	24·30	21·48	22·85
29	21·70	24·30	21·70	23·52
30	20·62	21·70	20·65	..
July 1	21·00	22·70	..	..
2	21·70	22·30	..	22·28
3	21·56	21·68	21·62	21·63
4	21·45	21·60	21·48	21·58
5	21·58	..	21·60	..
6	21·58	21·84	21·58	21·84
7	21·62	21·86	..	21·70
8	21·84	21·88	21·80	21·90
9	21·08	24·28	21·10	..
10	21·30	24·20	21·25	22·25
11	21·15	24·80	21·10	23·70
12	21·30	23·62	21·26	23·54
13	20·46	20·80	20·42	..
14	20·46	21·46	20·38	21·38
15	20·42	21·18	20·40	21·10
16	..	..	..	..
17	20·60	21·15	20·58	21·20
18	20·80	21·15	20·28	21·12
19	20·80	20·80	20·78	..
20	20·92	20·60	20·44	20·62
21	20·25	20·56	20·32	20·60

(c) PHYSICAL AND CHEMICAL CONDITIONS IN MANGROVE SWAMPS

By A. P. Orr and F. W. Moorhouse.

Mangrove swamps occur chiefly along tropical and subtropical coasts, especially where the mainland itself is characterized by rain forest. These swamps are essentially tidal and are generally associated with brackish water. They may, however, be associated with almost pure sea-water, and such are of common occurrence on the Low Wooded Islands (Steers, 1929), between the Barrier Reef of Australia and the mainland. On Low Isles where the mangrove swamp is a development on a coral reef (Text-fig. 1), it occupies a region which differs profoundly from the remainder of the reef. Instead of the usual sandy reef flat with its sparse growing coral, there is a region crowded with mangroves anchored by hooped stilt-like roots to a bottom consisting for the most part of black "mangrove" mud. This is described by Marshall and Orr in Vol. I, No. 5. The fauna and flora are described by Stephenson and others in Vol. III, No. 2.

There are large seasonal and diurnal fluctuations in the sea-water bathing the adjacent reef flat, and when we consider the shallowness and the different character of the bottom in the mangrove swamp, it might be expected that there we would find considerable fluctuations, but of a different nature.

The greater part of the swamp is uncovered at low tide, but, except for a few shingle banks, it is completely covered at most high tides. The level of the water in the swamp, however, does not normally correspond even approximately with the level of the sea outside (see Text-fig. 5). The rising tide invading the swamp can do so only through a series of gaps in its rim. Thus the tide rises for several hours before it invades the mangrove swamp. Similarly, after the rapid initial fall, it drains off from the swamp more slowly than the tide falls outside, and continues to drain off, though very slowly, even when the tide is rising outside. Various pools, varying from a few centimetres to half a metre or so in depth, are left after the mud has been uncovered. The bottom of these consists normally of a sandy mud. It was in such pools that the following observations were made, since these pools enabled the observations to be carried on over the whole of the low tide period.

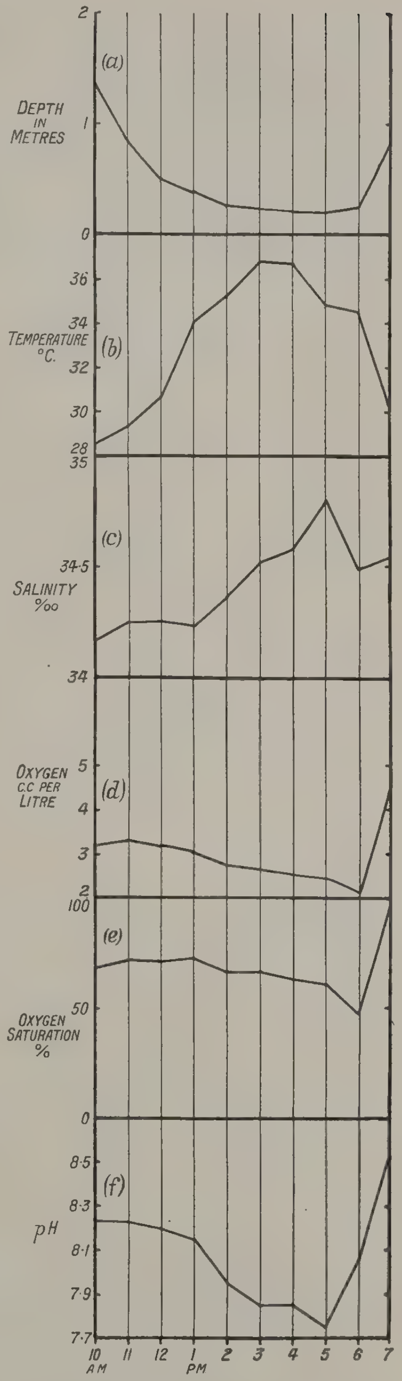
Observations were made during the spring tides, as it is then that the maximum changes occur both in physical and chemical conditions. The changes during neaps are minimal, since the isolation of the water bathing the swamp will last only a short time.

The observations were made both in summer and in winter, and the changes in the following conditions observed every one or two hours for varying periods of time: temperature, salinity, pH value, oxygen content and occasionally also phosphate content and excess base. The methods used were the same as those described by Orr in Vol. II, No. 3. A few preliminary observations made during the night in summer in a large sandy pool (Text-fig. 1, A) about 13 cm. deep at low tide showed that considerable changes might occur. The temperature remained close to that of the sea outside (about 29° C.), but there was some evaporation, the salinity rising from $35°/_{oo}$ to over $36°/_{oo}$. As on the reef flat, there was a considerable reduction in the oxygen content of the water, the saturation value falling as low as 22%, as compared with a value well over 90% for the sea outside at the same time. There is, of course, a considerable fall taking place on the reef flat at the same time, but whereas the latter is caused by the abundant animal and plant life, the former is more probably caused in large part by the oxidation of the organic material in the "mangrove" mud. The phosphate content of the pool showed no notable change, which is surprising, for the mangrove mud itself is very rich in soluble phosphate. The pool, however, is well protected by thick mangroves from disturbance by wind.

If the changes occurring at night are caused by oxidation of the organic material in the mud of the swamps, it would be anticipated that a fall in oxygen content and pH value would occur during the day as well. To test this a series of observations was made during the day in a similar position (see Text-fig. 1, B) again in summer. Observations were made hourly from 10 a.m. till 7 p.m., and the results are shown in Text-fig. 4 and Table VI.

Here, as at the first position, the water level shows the characteristic slow fall during ebb tide (Text-fig. 4, *a*). The tide outside was rising by 4 p.m., but no change in level occurred in the pool till 6 p.m., when the rise became sudden. The sea temperature outside was about 28·5° C., but in the shallow sheltered pool it rose to 36·8° C. (Text-fig. 4, *b*). In spite of this, the high humidity prevented evaporation, and the maximum salinity reached was only $34{\cdot}8^{\circ}/_{\circ\circ}$, as compared with open sea values of $34{\cdot}5^{\circ}/_{\circ\circ}$ (Text-fig. 4, *c*). In contrast to the reef flat, the oxygen content showed no rise during low tide, but, instead, a gradual fall (Text-fig. 4, *d*, *e*). The initial value at 10 a.m. (high tide) was unexpectedly low (68% saturation), but from then on the fall was gradual till 6 p.m., when it reached 48%. On the return of the tide, however, it reached a value of over 98% in an hour. The curves for pH value (Text-fig. 4, *f*) and excess base follow in general that for oxygen saturation, with one unexplained exception at 6 p.m.

The changes in oxygen saturation and pH values during the day among the mangroves are



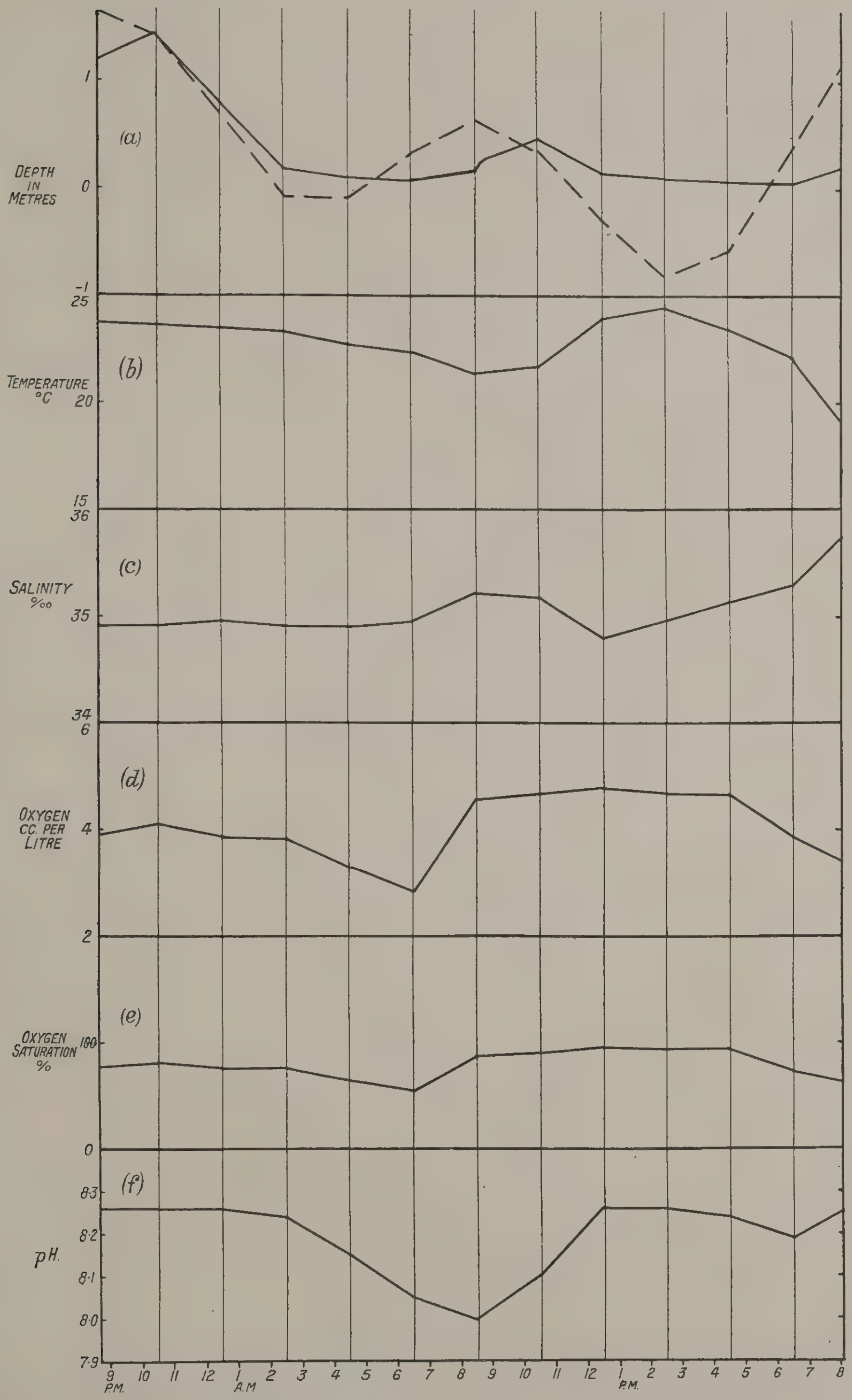
TEXT-FIG. 4.—Conditions in a pool in the mangrove swamp on Low Isles at position B during the day, 22nd February, 1929. (*a*) Depth; (*b*) temperature; (*c*) salinity; (*d*) oxygen content; (*e*) oxygen saturation; (*f*) pH value.

exactly the reverse of those occurring on the adjacent reef flat, and this difference is to be accounted for by the absence of coral with its symbiotic algae and an almost complete absence of attached algae. When we compare the results obtained during the day with those at night, it is found that at night there is even more evaporation than during the day, and that the oxygen fall at night is greater than during the day. This latter fact is probably due to the presence of phyto-plankton (see p. 106), which is producing oxygen during the day. Phosphate results again remained low, but the estimations were not very accurate because of an interfering substance in the water associated with the mangroves. The usual blue colour given by the reagent was obscured by the development of a yellow tint.

Table VI.—*Position B, Low Isles Mangrove Swamp, 22nd February,* 1929.

Time.	Depth in cm.	Temperature (°C.).	Salinity ‰.	pH.	O_2 c.c. per l.	O_2 saturation %.
10 a.m.	136	28·60	34·17	8·23	3·17	68·2
11 ,,	84	29·33	34·25	8·23	3·31	72·2
12 noon	50	30·68	34·25	8·20	3·17	71·2
1 p.m.	39	34·10	34·23	8·15	3·05	72·9
2 ,,	26	35·20	34·36	7·95	2·73	66·6
3 ,,	24	36·80	34·52	7·85	2·66	66·9
4 ,,	22	36·70	34·58	7·85	2·53	63·7
5 ,,	20	34·80	34·80	7·75	2·46	61·0
6 ,,	25 at 6 p.m. 37 ,, 6.13 ,, 43 ,, 6.20 ,, 64 ,, 6.37 ,,	34·49	34·49	8·05	2·11	48·1
6.55 ,,	81	30·07	34·54	8·52	4·43	98·4

A third series of observations was made in winter (Text-fig. 5 and Table VII), this time over a period of 24 hours, the water being examined every two hours. The position chosen was in one of the passages by which water enters and leaves the swamp (see Text-fig. 1, C). The bottom was composed of fine sand, with a few attached algae. Except at slack water there was always a current in the passage. In June, when the observations were made, the day and night tides at springs are very unequal. This is shown well in Text-fig. 5, *a*; the day high tide is unusually high. It has been assumed in the comparison of the curves that the level of water in the mangrove swamp and in the sea was the same at high tide at 10.30 p.m. The changes in general are much less marked than during the summer. The temperature range, which is small (Text-fig. 5, *b*), and the evaporation, which is moderate (Text-fig. 5, *c*), are probably largely influenced by the S.E. trade wind, the constant wind of winter, which blew freshly during the course of the observations. As was anticipated, the oxygen saturation values (Text-fig. 5, *d*, *e*) fell continuously during the night low tide, but they showed little or no change during the day low tide. They did not, however, reach a value of 100%, although the water on the adjacent reef flat must have been considerably supersaturated during this time. The fall in oxygen saturation in the evening was more rapid than expected, although the tide was beginning to invade the swamp again. The pH values (Text-fig. 5, *f*) followed those for oxygen saturation with again one exception in the evening. Although the position was somewhat different from those



TEXT-FIG. 5.—The diurnal changes in the water in a passage in the mangrove swamp on Low Isles (position C) during winter, 8th June, 1929. (*a*) —— depth in passage, ------ sea-level change in the Anchorage; (*b*) temperature; (*c*) salinity; (*d*) oxygen content: (*e*) oxygen saturation; (*f*) pH value.

examined in summer, it seems safe to conclude that changes are more marked then than in winter.

TABLE VII.—*Position C, Low Isles Mangrove Swamp, 8th–9th June,* 1929.

Time.	Depth in cm.	Temperature (°C.).	Salinity ‰.	pH.	O_2 c.c. per l.	O_2 saturation %.
8.40 p.m.	122	23·75	34·91	8·26	3·91	77·7
10.30 ,,	145	23·63	34·91	8·26	4·11	81·6
12.30 a.m.	79	23·50	34·96	8·26	3·85	76·4
2.30 ,,	19	23·37	34·91	8·24	3·83	75·7
4.30 ,,	10	22·75	34·91	8·15	3·29	64·5
6.30 ,,	8	22·32	34·96	8·05	2·84	55·3
8.30 ,,	18 at 8.30	21·38	35·22	8·00	4·57	87·7
	24 ,, 8.40					
	28 ,, 8.50					
10.30 ,,	46	21·69	35·18	8·10	4·68	90·2
12.30 p.m.	15	23·96	34·80	8·26	4·77	95·2
2.30 ,,	9	24·41	34·96	8·26	4·67	93·9
4.30 ,,	7	23·48	35·14	8·24	4·67	93·1
6.30 ,,	6	22·12	35·29	8·19	3·86	73·2
8.5 ,,	18	19·10	35·74	8·25	3·40	63·0

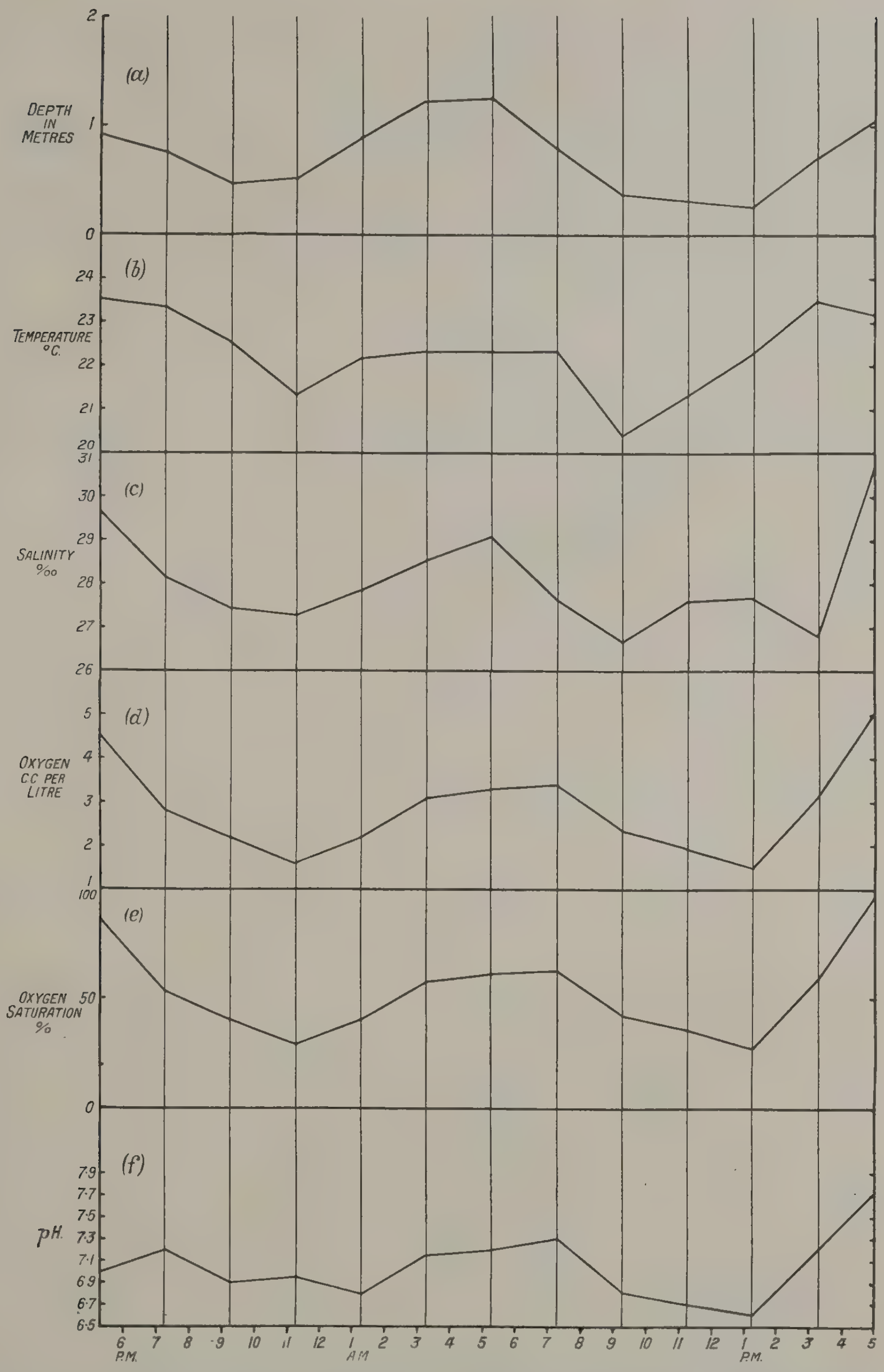
The microplankton of the water in the mangrove swamp differed little from that found in the Anchorage, except that the number of diatoms and dinoflagellates was usually lower. There was no significant difference between samples taken at high and low tide. On one occasion the sample at low tide was muddy, and contained a very large number of small green thecate peridinians, which were absent from the waters outside. They may have been living on the surface of the mud.

TABLE VIII.—*Daintree River Mangrove Swamp, 30th June to 1st July,* 1929.

Time.	Depth in cm.	Temperature (°C.).	Salinity ‰.	pH.	O_2 c.c. per l.	O_2 saturation %.
5.15 p.m.	91	23·51	29·64	7·00	4·52	86·6
7.15 ,,	76	23·34	28·14	7·20	2·80	53·3
9.15 ,,	46	22·52	27·43	6·90	2·17	40·4
11.15 ,,	51	21·34	27·26	6·95	1·60	29·1
1.15 a.m.	89	22·16	27·82	6·80	2·19	40·6
3.13 ,,	122	22·30	28·54	7·15	3·09	57·7
5.15 ,,	125	22·32	29·08	7·20	3·28	61·4
7.15 ,,	79	22·30	27·61	7·30	3·36	62·2
9.15 ,,	36	20·38	26·66	6·80	2·35	41·9
11.15 ,,	31	21·29	27·59	6·70	1·94	35·3
1.15 p.m.	25	22·30	27·66	6·60	1·48	27·5
3.15 ,,	71	23·48	26·79*	7·20	3·14	58·9
5.0 ,,	104	23·16	30·72	7·72	5·03	96·6

* Duplicate analyses.

The mangrove swamp on Low Isles is small in area compared with the swamps which occur along the coast, especially at river mouths, and for a comparison of winter changes in Low Isles swamp with those in the swamps on the mainland, a single series of observations



Text-fig. 6.—The diurnal changes in the water of a pool in the mangrove swamp near the mouth of the Daintree River. (*a*) Depth; (*b*) temperature; (*c*) salinity; (*d*) oxygen content; (*e*) oxygen saturation; (*f*) pH value.

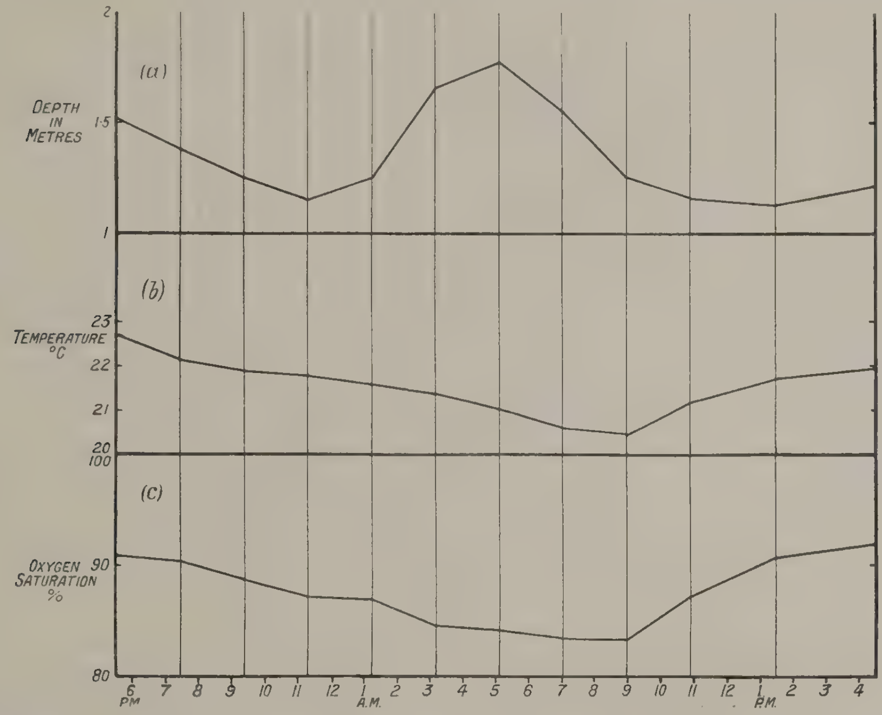
was made in one of the latter over 24 hours in winter. The mangroves which occupy a large area at the mouth of the Daintree River (see Russell and Orr, Vol. II, No. 1, Plate I) were most convenient, and a position was chosen in a pool isolated at low tide a short distance from the river itself. The bottom of the pool was composed of fine "mangrove" mud easily stirred up by the movement of small fish, which were numerous. Hermit crabs, gastropods and oysters were also common. Here the mangrove area is exposed at low tide and invaded only about half tide. The mangrove mud near the pool was found by boring to be about 6 ft. thick. Below this the mud was mixed with a very coarse quartz sand to a depth of 9 ft., the limit of the bore.

The results of the observations are shown in Text-fig. 6 and Table VIII. There are very considerable fluctuations in salinity (Text-fig. 6, *c*), but in this case these are not caused by evaporation, but by the mixture of river and sea-water, which invades the swamps at high tide. The temperature changes also (Text-fig. 6, *b*) are related to the tidal rise and fall. The changes in oxygen content and pH value (Text-fig. 6, *d*, *e* and *f*) cannot be explained by admixture with river water, but are caused partly by the animals present and partly by oxidation of the mangrove mud itself. The mangroves here were much thicker than in the positions examined on Low Isles, so that only diffuse light could enter and there were no attached algae. The fall in oxygen saturation was almost the same during both the night and the day low tides, and was much greater than was met with in winter on Low Isles, the minimum value reached being 29%. Even during high tides the values did not go much above 60% saturation, while that of the sea outside was well over 90%. pH values here, as in the swamp on Low Isles, followed the values for oxygen saturation. They were much lower than was the case in Low Isles mangrove swamp and, as they were beyond the range for McClendon's buffer series (1917), McIlvaine's mixtures (1921) were used instead.

TABLE IX.—*Daintree River, 30th June to 1st July*, 1929.

Time.	Depth in cm.	Temperature (°C.).	pH.	O_2 c.c. per l.	O_2 saturation %.
5.30 p.m.	152	22·71	6·85	5·71	90·9
7.26 ,,	138	22·15	6·70	5·72	90·4
9.22 ,,	125	21·90	6·75	5·65	88·8
11.18 ,,	115	21·79	6·75	5·55	87·1
1.14 a.m.	125	21·60	6·70	5·56	87·0
3.10 ,,	166	21·37	6·70	5·43	84·6
5.06 ,,	177	21·05	6·75	5·43	84·2
7.02 ,,	155	20·60	6·75	5·42	83·4
8.58 ,,	126	20·45	6·80	5·42	83·3
10.54 ,,	116	21·17	6·75	5·61	87·1
1.30 p.m.	113	21·70	6·75	5·78	90·6
4.30 ,,	121	21·93	6·75	5·84	91·8

At the same time, as the observations were being made on the mangrove swamp, the river itself was examined. To avoid disturbance by admixture of sea-water, a position was chosen about 15 miles from the mouth of the river, where the salinity was negligible. Even here there was a considerable tidal change of level (see Text-fig. 7, *a*), but the other changes recorded were due entirely to changes in fresh water. The river is, except during rainy weather, slow flowing and clear, and has a sandy bottom. The results are shown in Text-fig. 7 and Table IX. Although there were considerable changes in the air temperature, the river temperature changed only slightly. During the night this difference of temperature caused a thick fog on the river, which was not dispelled till 10 a.m. This fog, lasting well into the morning, is of common occurrence in winter. The oxygen saturation showed only very slight fluctuations, corresponding with light and darkness and temperature changes. The lateness of the day rise may have been due to the thick fog. When compared with rivers in temperate waters (Butcher, Pentelow and Woodley, 1930) the changes are very small indeed. The oxygen never reached saturation values, and changes in pH values were also small. It is apparent that the river water is in no way responsible for the changes in the mangrove swamp at the mouth. The river contained a large amount of soluble silicate, but very little soluble phosphate.



TEXT-FIG. 7.—The diurnal changes in the water of the Daintree River about 15 miles above its mouth. (*a*) Depth; (*b*) temperature; (*c*) oxygen saturation.

Compared with fresh-water swamps in the tropics, mangrove swamps show much greater diurnal fluctuations. Carter and Beadle (1930) found in fresh-water swamps in Paraguay that large areas were often almost denuded of oxygen and contained but little animal life or phytoplankton. Mangrove swamps, being flooded twice daily with water rich in oxygen, are never entirely denuded of it, but show an intertidal fall. Thus they can support a much larger population than these tropical fresh-water swamps. The rising tide also introduces food material in the form of zoo- and phytoplankton, while it is probable that there are also numerous microscopic algae living on the mud.

CONCLUSIONS.

1. There are diurnal fluctuations in temperature, salinity, pH value and oxygen content in the mangrove swamp on Low Isles reef flat.
2. There is usually a night fall and a day rise in temperature ; salinity rises at low tide ; pH value and oxygen saturation fall at low tide.
3. These changes are largest at spring tides and lowest at neaps, and are greater in summer than in winter.
4. Similar changes occur in the mangrove swamp at the mouth of the Daintree River, but there changes in pH value and oxygen saturation are greater.
5. The Daintree River itself shows very small diurnal changes compared with rivers in temperate regions.

We have to thank various members of the expedition for considerable help in the course of this work, more particularly Miss S. M. Marshall and Mr. A. G. Nicholls.

REFERENCES.

Butcher, R. W., Pentelow, F. T. K., and Woodley, J. W. A. 1930. Variations in Composition of River Waters. Int. Rev. Hydrobiol. Bd. XXIV, Heft 1–2, pp. 47–80, text illust.

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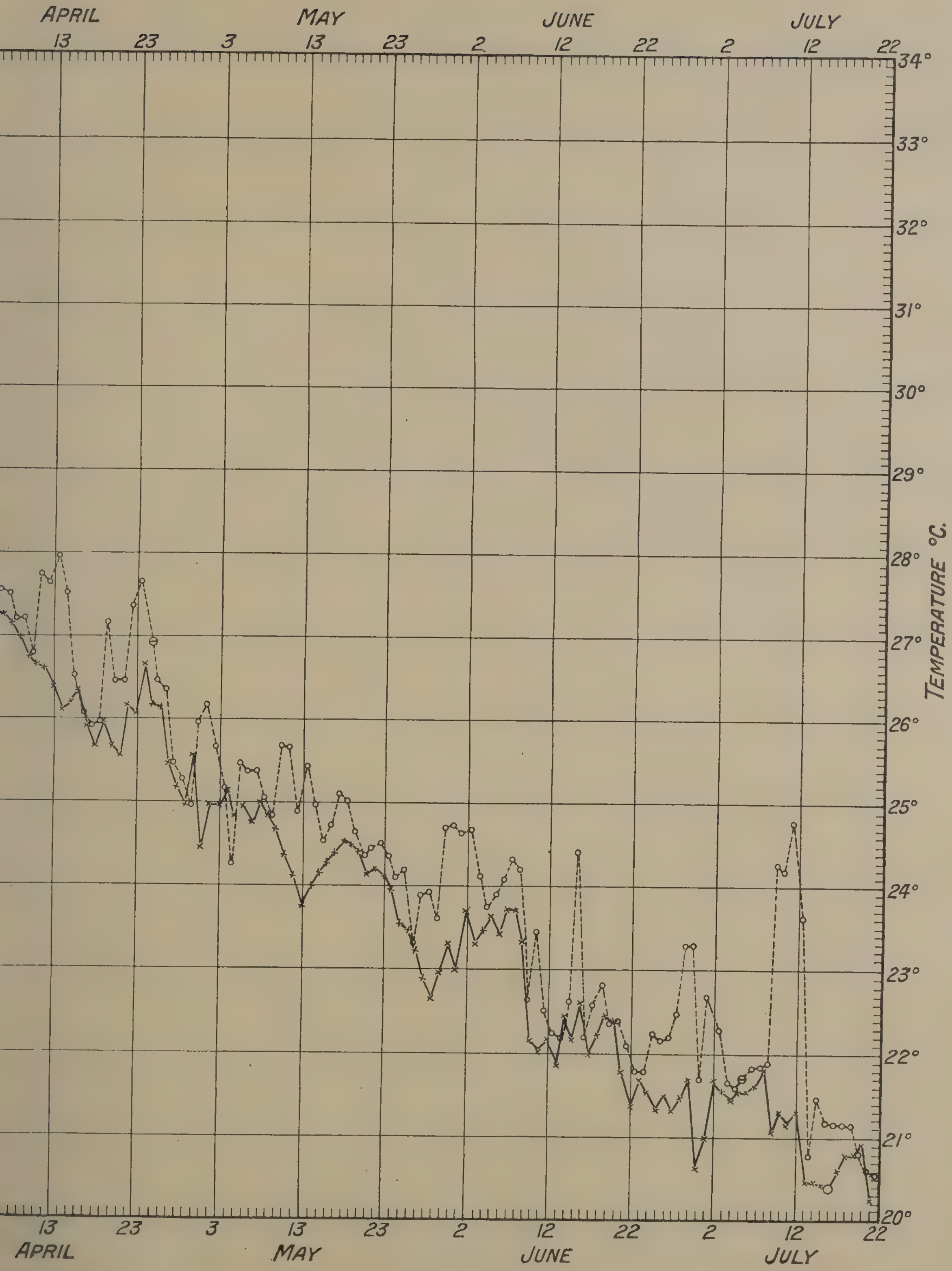
DESCRIPTION OF PLATE I.

Morning readings joined by continuous line. Afternoon readings joined by broken line.



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CONCLUSIONS.

1. There are diurnal fluctuations in temperature, salinity, pH value and oxygen content in the mangrove swamp on Low Isles reef flat.
2. There is usually a night fall and a day rise in temperature; salinity rises at low tide; pH value and oxygen saturation fall at low tide.
3. These changes are largest at spring tides and lowest at neaps, and are greater in summer than in winter.
4. Similar changes occur in the mangrove swamp at the mouth of the Daintree River, but there changes in pH value and oxygen saturation are greater.
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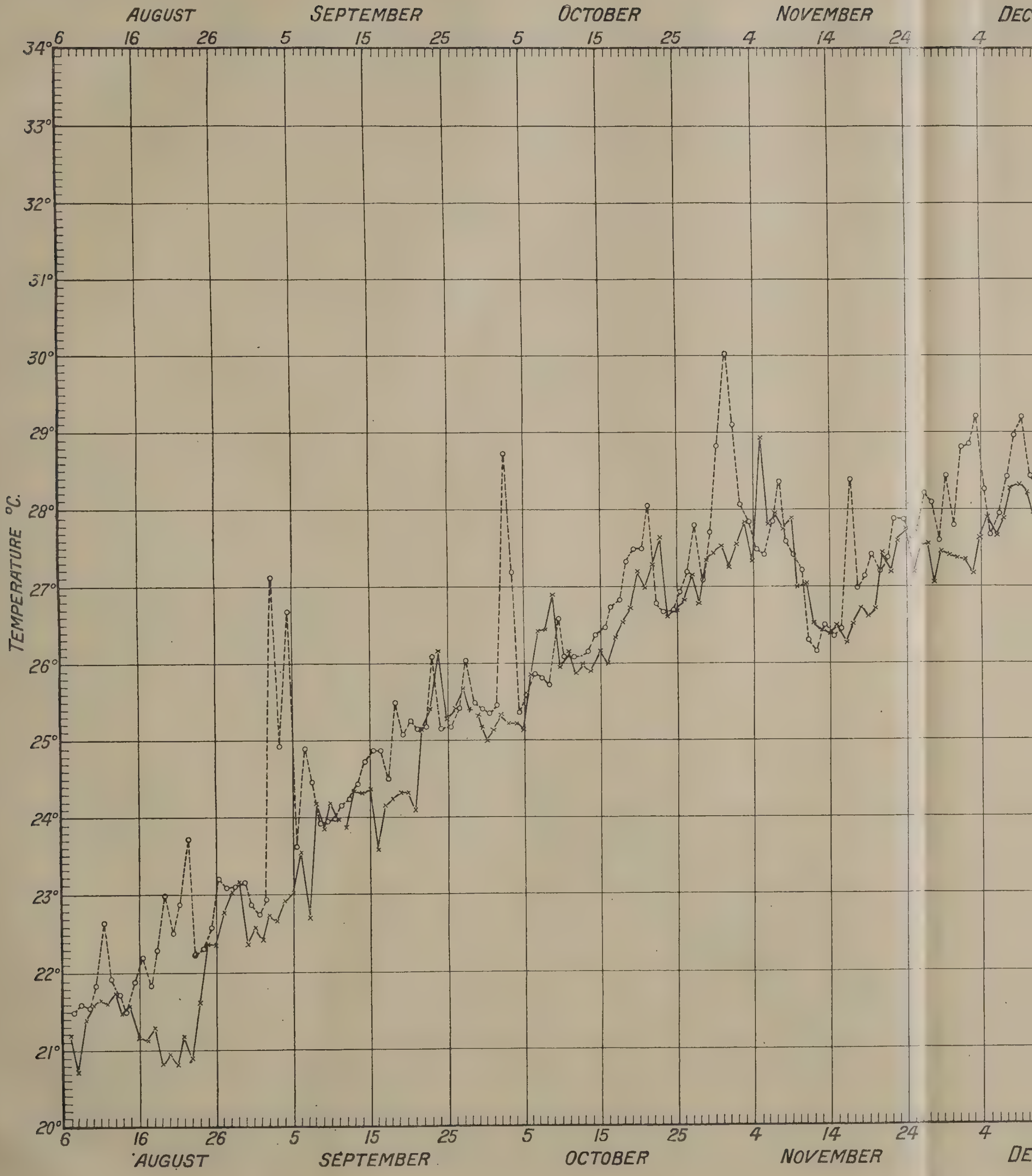
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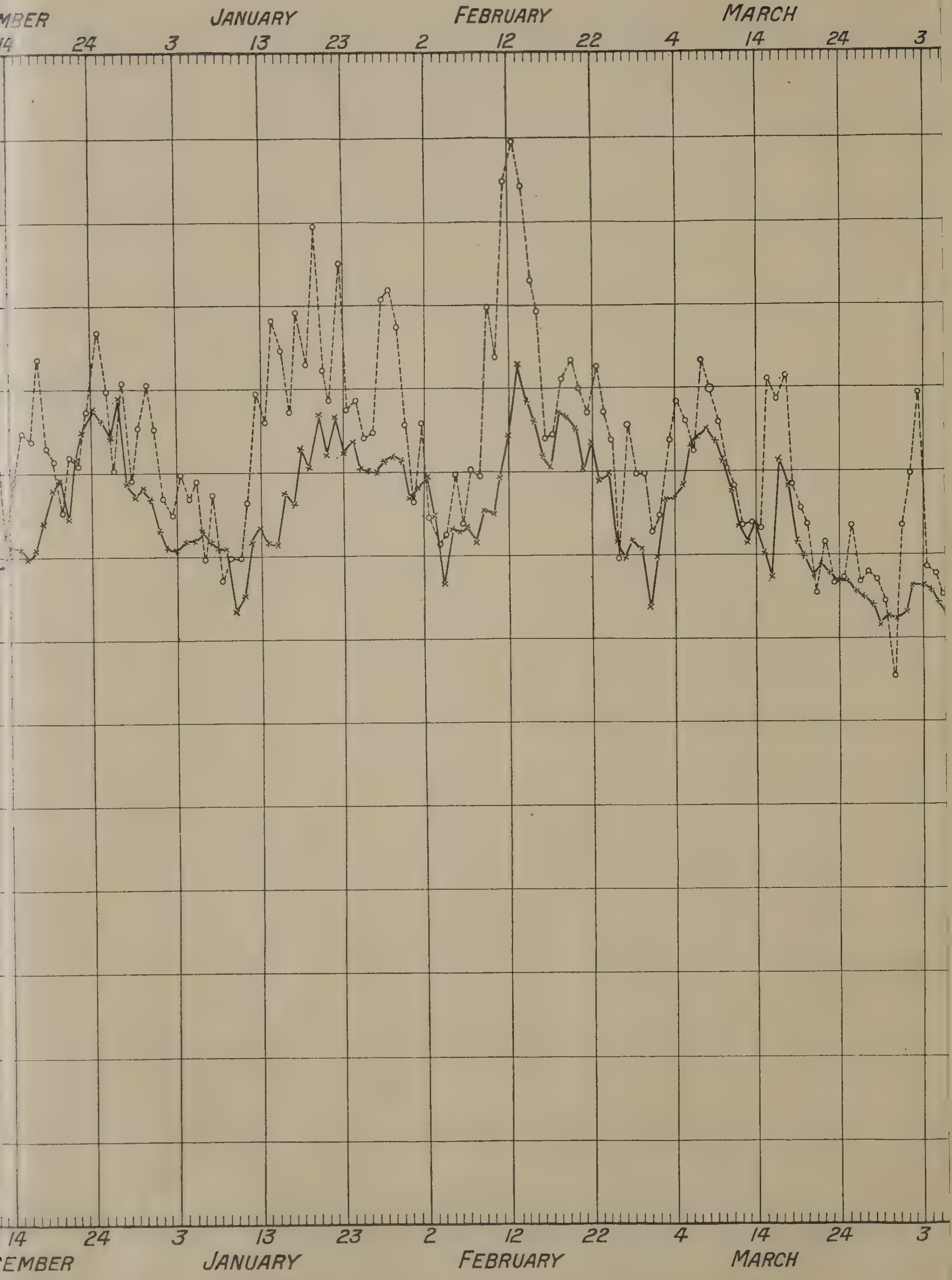

Temperatures of Surface Waters, Anchorage, Low Isles.

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PACIFIC OCEANIC FISHERY
INVESTIGATIONS

THE PRODUCTION OF MICROPLANKTON IN THE GREAT BARRIER REEF REGION

BY

SHEINA M. MARSHALL, B.Sc.
Naturalist at the Marine Station, Millport

WITH FOURTEEN FIGURES IN THE TEXT, AND FIVE TABLES

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PART I

INTRODUCTION.

Our knowledge of the microplankton of tropical waters has been gained almost entirely from observations made during the course of oceanographical cruises, so that successive samples have usually been taken in different localities. By this means little can be learned about the annual variation in production, and the results tend to show geographical rather than seasonal distribution. When opportunity offered, therefore, it was decided to carry out continuous observations in one place, the lagoon of the Great

Barrier Reef, for a year, and thus to compare the results in the tropics with those from temperate waters, where much of this kind of work has been done. The collection of water samples from various depths formed part of the routine work at the plankton and hydrographic stations. In the descriptions which follow it must be understood that the water samples referred to (apart from those of Series II) are those taken by the Nansen-Petterson water-bottle at the Hydrographic Stations (*cf.* the preceding papers in this volume), and are part of the same samples as were used for chemical analyses.

Karsten (1907), during the "Valdivia" Expedition, found that on approaching land, even if it were only a coral atoll, the character of the phytoplankton changed immediately from oceanic to neritic. It was therefore not to be expected that the position chosen inside the Great Barrier Reef lagoon should show an oceanic type of phytoplankton, and it was in fact found to be for the most part neritic.

The microplankton results are based on three series of water samples:—Series I: Samples taken from the weekly station three miles east of Low Isles from depths of 0, 5, 10, 15, 20 and 28 metres. These include samples from two stations in a similar position to the weekly station, but further north.

Series II: Samples taken in a glass sample bottle two or three times a week, usually at a depth of 2 metres from a position just north of Low Isles (see Vol. II, No. 1, Plate II). In stormy weather these were taken nearer the island than usual, and on three occasions they were taken in the Anchorage.

Series III: Samples taken from outside the Great Barrier Reef or in passages through it.

Samples were usually examined fresh on the day they were taken or the day following, so as to include in the count the small naked dinoflagellates and coccolithophores which are destroyed by fixation, but when this was not possible they were preserved according to Gran's method (1912) in strong Flemming solution (10 c.c. to 250 c.c. sea-water). The quantity centrifuged was either 100 c.c. or 200 c.c. 100 c.c. was used in Series I up till 2nd October, and throughout in Series II. 200 c.c. was used in Series I after 2nd October and throughout in Series III. They were centrifuged for 10 minutes at a speed of 3000 revolutions per minute. Most of the fluid was then drawn off carefully by a siphon (which was made with an upturned tip, so as to avoid disturbing the deposit), and the remainder, about 20 c.c., was recentrifuged in smaller tubes.

Since the main object was to study the plant production as a whole in its relation to the chemical and physical factors in the sea-water, no great attention was paid to identifying individual species. The diatoms and dinoflagellates were grouped as far as possible into their genera, but a large number of diatoms belonging to the Pennatae, which it was impossible to classify with the literature available, were simply grouped under the general term "Pennate Diatoms." These belonged largely to the genera *Nitzschia* and *Navicula*. The group proved unexpectedly important, although many of the forms do not really belong to the plankton at all, but are bottom-living forms which have been carried up into the overlying water. The ribbon or star-shaped colonies characteristic of the truly planktonic pennate diatoms were not abundant.

Certain differences can be noted among the different series. The number of organisms in Series II, that is, the samples taken close to Low Island, was always higher than at the weekly station, and pennate diatoms were the most numerous type. They decreased at the weekly station, and were least numerous (as were organisms in general) at the outside stations of Series III. Conversely, certain oceanic forms, such as the coccolithophores and some of the tintinnids, were most numerous at the outside stations, scarcer at the weekly station and rare or absent near the island. The day-to-day fluctuation in numbers was very marked near the island, but this series served as a useful check upon the samples from the weekly station. Any marked increase in numbers was usually found at both positions at the same time, and the seasonal distribution of the organisms was the same at both.

DIATOMS.

Series I and II.

When work began at the weekly station in July and August (see Text-figs. 1, 2, 3 and 4, and Tables III and IV) diatoms were, as a rule, most numerous at the surface, although there was little difference between samples from the surface and 28 metres. Pennate diatoms predominated, *Rhizosolenia* and *Chaetoceros* being the only other important forms. The numbers varied from 500 to over 3000 diatom cells per litre. Near the island, where the diatom flora was otherwise similar, they were more numerous, varying from 2000–10,000 cells per litre. This number increased towards the end of the month, and on 29th August there was a sudden rise near the island to 28,000, and a further rise the following day to 167,400 diatom cells per litre—the highest figure reached during the whole year. Of this number *Chaetoceros* spp. formed 118,000 and pennate diatoms 26,000, while *Rhizosolenia* (4750), *Bacteriastrum* (2550), *Hemiaulus* (5500) and *Leptocylindrus* sp. (10,000) were also important. The weekly station was worked on the following day and a marked increase was found there also, greatest at the surface (nearly 30,000), but marked also in the deeper layers (Text-fig. 2). The composition of the surface sample was much the same as that of the one near the island, but below the surface pennate diatoms predominated and *Rhizosolenia* was as important as *Chaetoceros*.

This rich diatom flora disappeared as quickly as it had appeared. On 4th September at the weekly station numbers had fallen to their usual value, and they continued to fall in the succeeding weeks. From 26th September to 6th November numbers were rarely above 1000 per litre, and usually below 500. The decrease in numbers was less marked near the island, chiefly because the pennate diatoms were still numerous there. On 16th November another sudden increase took place at the weekly station, but it was not so great as that of 31st August, and the depth distribution was irregular, with maxima at 10 (9300) and 20 (8500) metres. This time *Chaetoceros* and pennate diatoms were about equally important and other species played a smaller part. At the same time (12th to 16th November) there was a similar increase near the island. The high numbers disappeared rapidly again in both places, and by 21st November conditions were the same as before the increase.

The rapid disappearance of diatoms after these increases is a striking fact. It might be supposed that it was due to a movement of large masses of water, and that a body of water especially rich in diatoms had been struck on one particular day. This explanation is ruled out by the fact that, as will be seen later, the increase apparently takes place over a wide area.

During the next few months (21st November to 18th February) diatom numbers were usually low, except in the bottom samples. Pennate diatoms still predominated, but

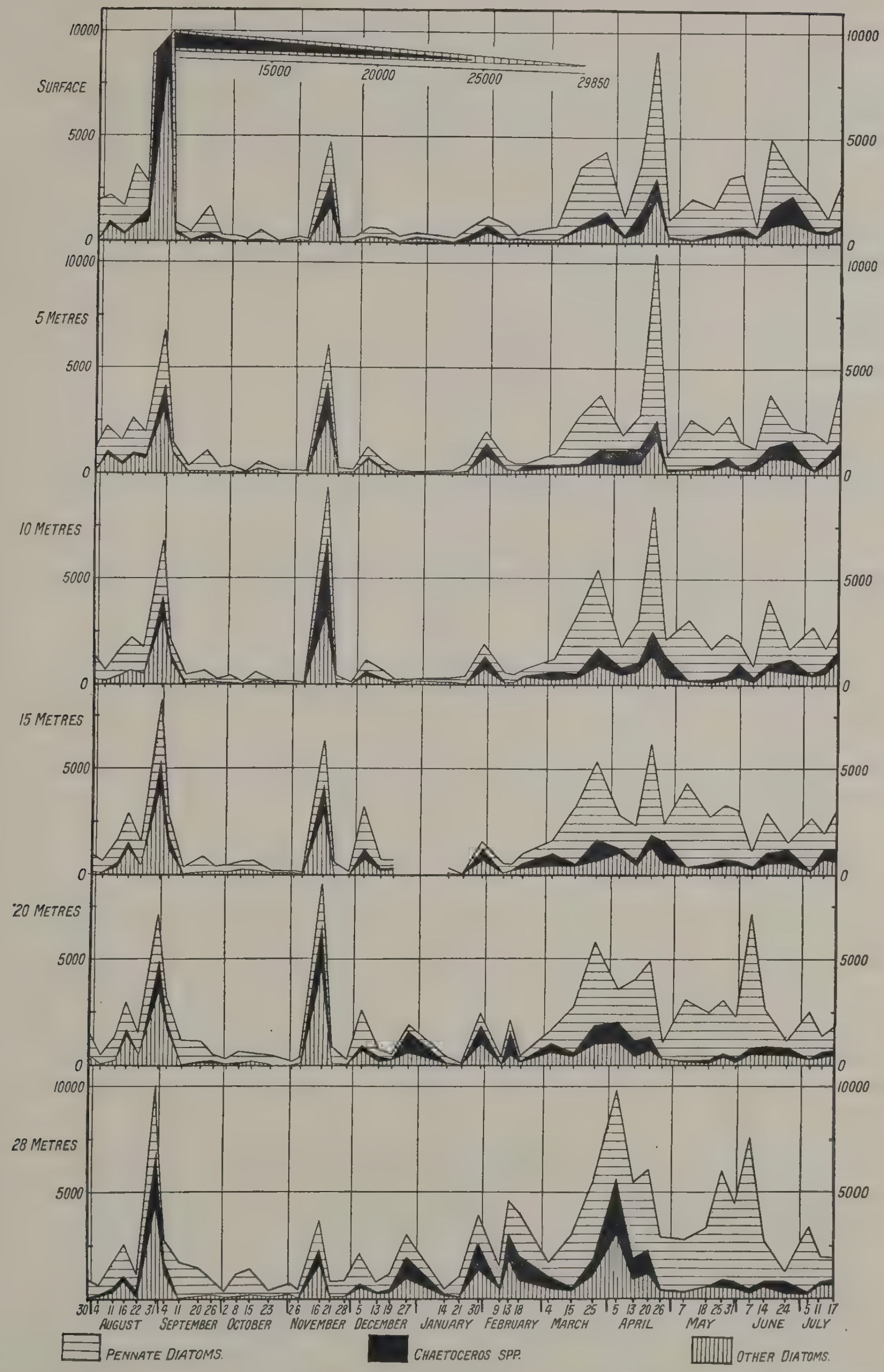
Chaetoceros and other forms played a larger part than in the September to November period. This was especially the case on 27th December, 30th January, and from 13th February onwards. The maximum numbers were (except on 5th December) always at the bottom. There were often few down to 15 or 20 metres, and then there was a sudden rise, so that the 28-metre sample might be two to twelve times richer than the surface sample. This is probably correlated with the calm weather of that time. In the samples of Series II near the island numbers fluctuated a good deal during December, January and February. They were, as a rule, lower than during the previous months, except for a rise in mid-December and another (corresponding to one at the weekly station) in the end of January.

The weekly station was not worked between 18th February and 4th March, but two stations were worked in a similar position in the lagoon of the Great Barrier Reef, considerably to the north (see Vol. II, No. 1, Plate I). At both the diatoms were numerous and *Chaetoceros* predominated. The numbers were highest (nearly 10,000) and the maximum was at the surface in the more southerly station off Cape Bedford. Off Lizard Island the maximum (6000) was at 20 metres. It is possible that this increase occurred at Low Isles also.

On and after 15th March there was a great rise in numbers of all species at all depths, although pennate forms still predominated. These higher numbers, varying from 2000–5000 cells per litre, reached their maximum on 20th April, when there were 5000–10,000 in every sample from top to bottom. After this, from 26th April to 17th July, when the observations ended, the number of diatoms remained high—usually over 2000 cells per litre (Text-figs. 1, 3 and 4). The maximum number was usually at or near the bottom, although towards the end in June and July it was occasionally found at the surface. Pennate diatoms predominated, except on 24th June, when *Chaetoceros* spp. were more abundant. Near the island also there was a definite and lasting rise in numbers about the middle of March. As at the weekly station, all species of diatom increased, the pennate forms being richest and *Chaetoceros* spp. next. The numbers in June and July, 1929, both at the weekly station and near the island, were higher than those for July and August, 1928, but in other respects the samples were similar.

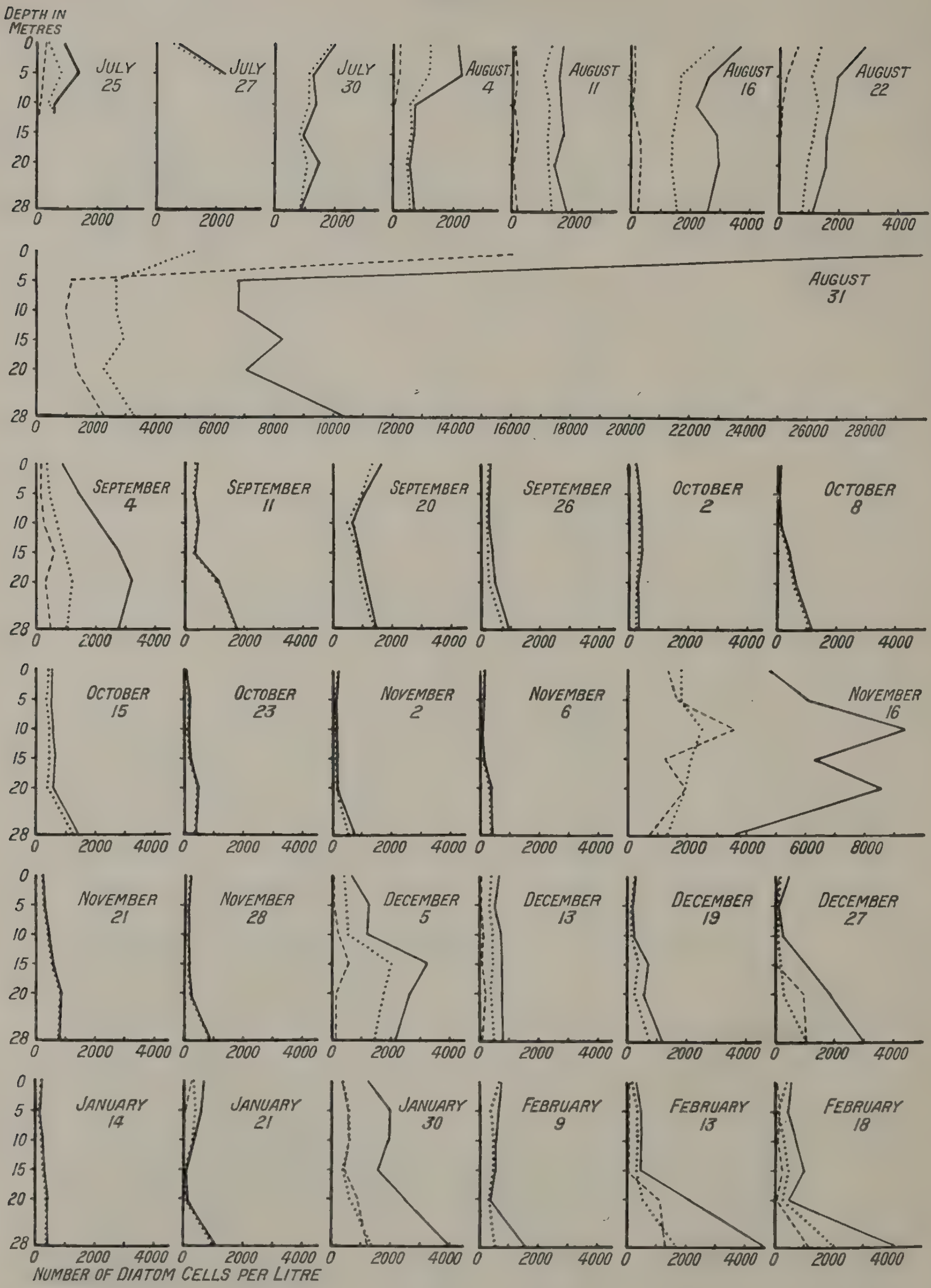
Relationship to Chemical and Physical Factors.

It is obvious that there was no real seasonal cycle of diatom growth here. The main increases which did come, 31st August, 16th November, 26th February and 20th April, were scattered over the year, and the second of them came at a time which was otherwise very poor in diatom growth. They lasted only for a short time, never over two successive weeks at the weekly station and, as can be seen from the samples of Series II, rarely more than three or four days. After a diatom increase in temperate waters the diatoms are found sinking into deeper water, so that the maximum number is found at successively greater depths. Nothing of the kind could occur in the Barrier Reef lagoon, because the wind kept the water thoroughly mixed from top to bottom most of the time. In calm weather the diatoms will sink to the bottom, and this was probably the main cause of the high numbers in the bottom samples during the summer. If the dates on which diatom numbers were high are compared with the wind force (Text-figs. 2 and 3), it is seen that in most cases the high bottom figures came in calm weather, or on calm days after windy weather. Two notable exceptions to this are 5th April and 7th June (Text-fig. 2), but on

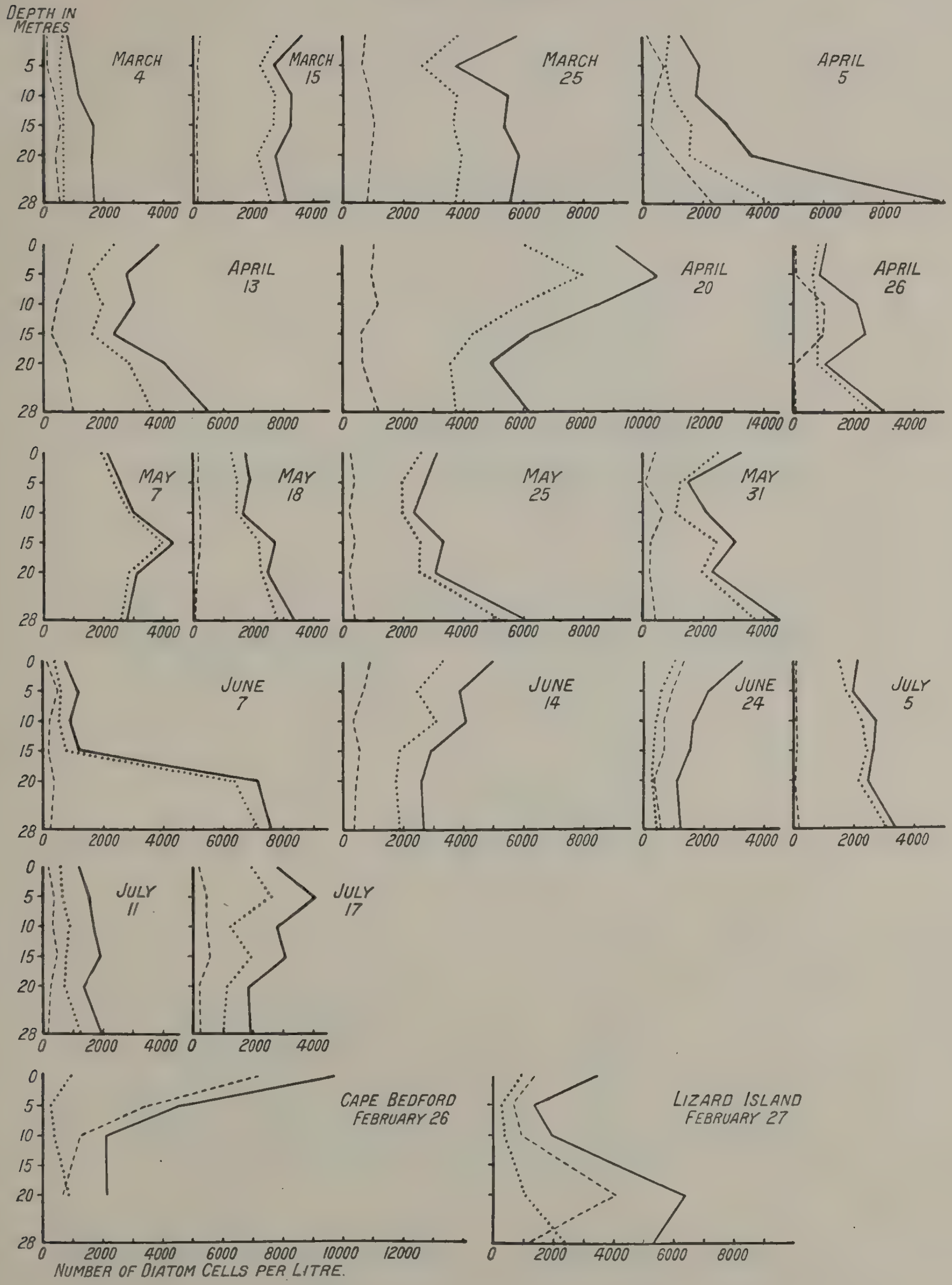


TEXT-FIG. 1.—Number of diatom cells per litre at 0, 5, 10, 15, 20 and 28 metres at the weekly station (Series I).

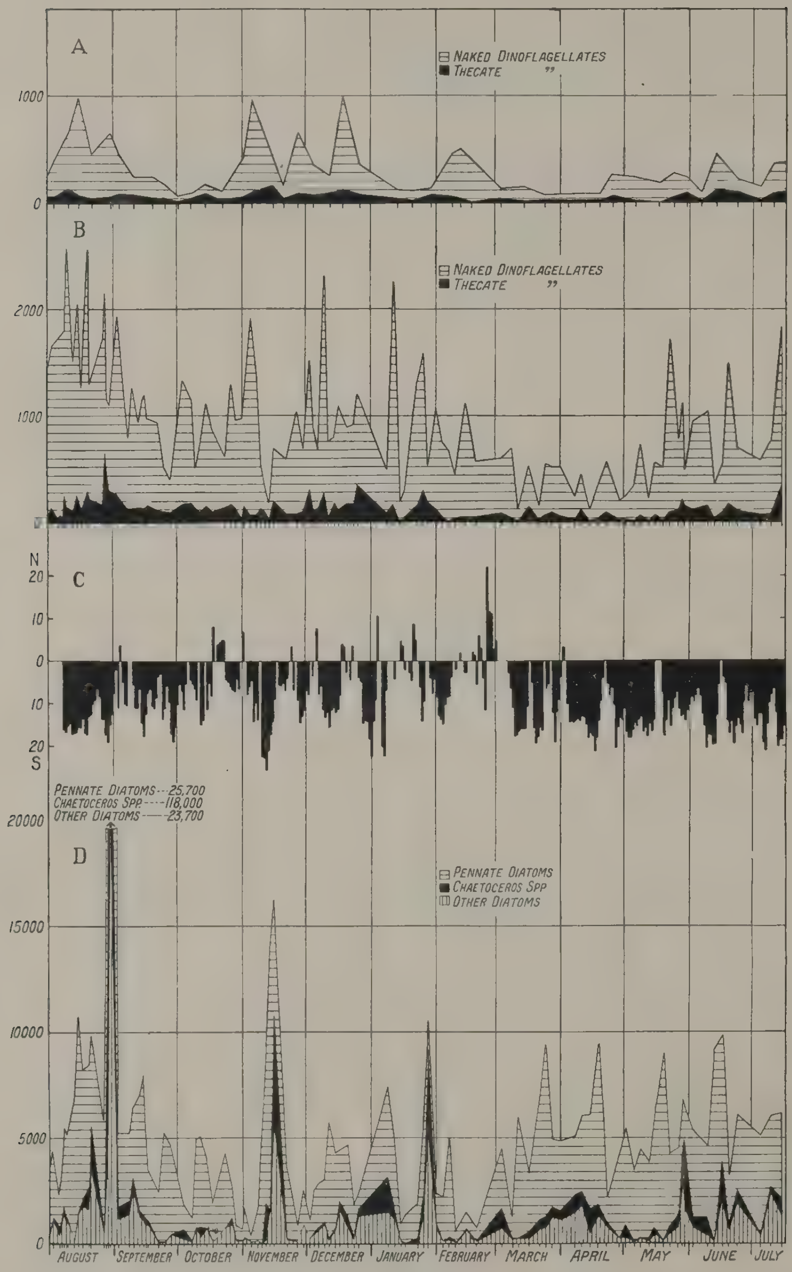
TEXT-FIG. 2.


DEPTH IN METRES
0
5
10
15
20
28
JULY 25
JULY 27
JULY 30
AUGUST 4
AUGUST 11
AUGUST 16
AUGUST 22
0
2000
4000
AUGUST 31
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
SEPTEMBER 4
SEPTEMBER 11
SEPTEMBER 20
SEPTEMBER 26
OCTOBER 2
OCTOBER 8
OCTOBER 15
OCTOBER 23
NOVEMBER 2
NOVEMBER 6
NOVEMBER 16
6000
8000
NOVEMBER 21
NOVEMBER 28
DECEMBER 5
DECEMBER 13
DECEMBER 19
DECEMBER 27
JANUARY 14
JANUARY 21
JANUARY 30
FEBRUARY 9
FEBRUARY 13
FEBRUARY 18
NUMBER OF DIATOM CELLS PER LITRE

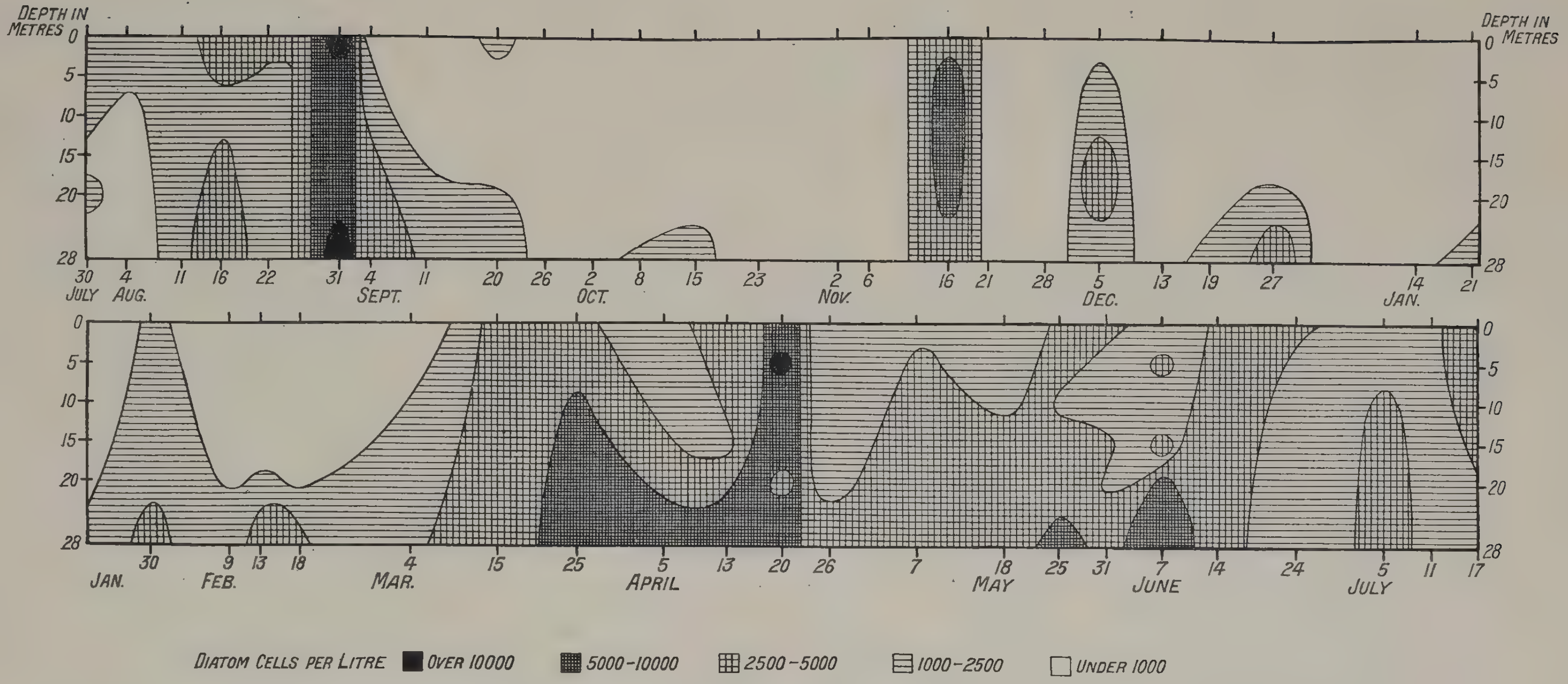
TEXT-FIG. 2—*continued.*



TEXT-FIG. 2.—Depth distribution of diatoms (number of cells per litre) at the weekly station.
——— All diatoms. - - - - - *Chaetoceros*. ...... Pennate diatoms.

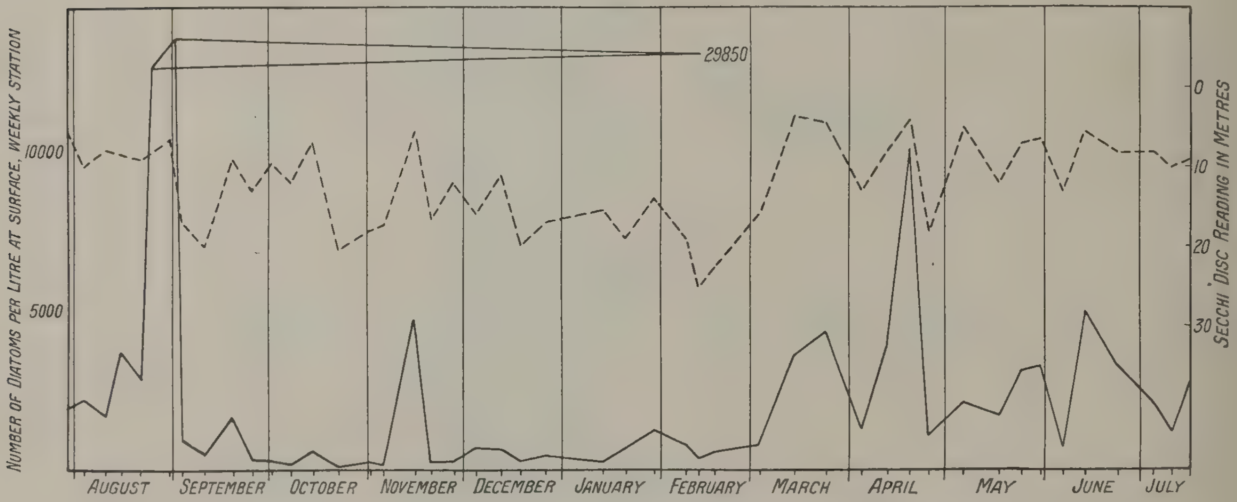


TEXT-FIG. 3.—(A) Number of dinoflagellates per litre in the surface samples from the weekly station. (B) Number of dinoflagellates per litre in samples of Series II. (C) Average daily wind-force in miles per hour, taking all winds from N.W. to N.E. as N. and from S.W. to S.E. as S. (D) Number of diatom cells per litre in samples of Series II.



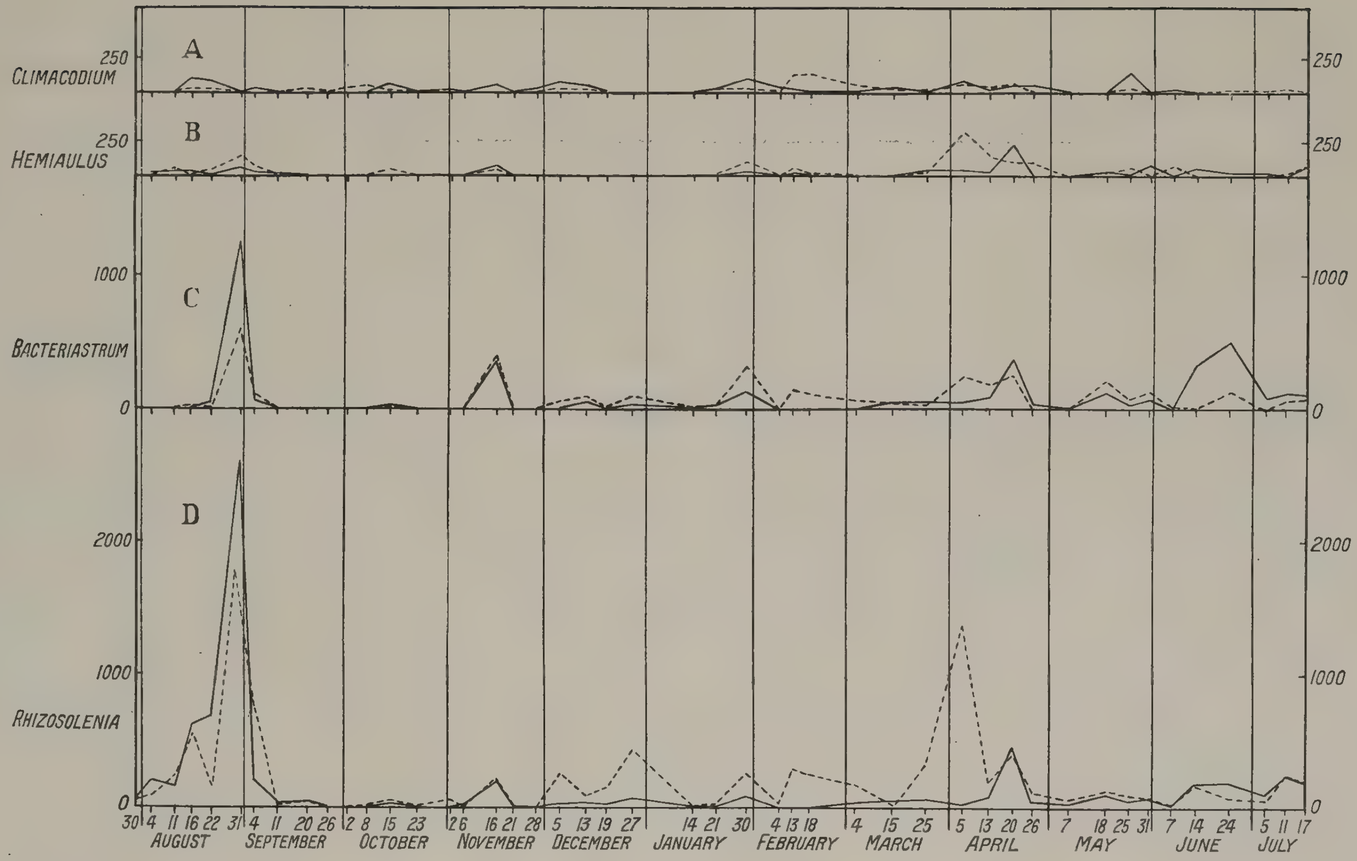
TEXT-FIG. 4.—Diagram showing the number of diatoms at all depths throughout the year at the weekly station (Series I).

these two days the salinity results show that there had been an influx of more saline water along the bottom, which may have caused a current strong enough to stir up the diatoms. Conditions are more complicated after the S.E. trade begins in March, for the strong wind causes currents which may stir up diatoms living on the bottom or those which have sunk there. The high figures in the bottom samples were due to planktonic as well as pennate forms, and samples which were rich in diatoms were usually rich in detritus also. The depth of disappearance of the Secchi disc (Text-fig. 5) is a good measure of the amount of detritus in the water, and the peaks on this curve, *i. e.* the dates on which it disappeared most quickly, correspond in many cases very closely to peaks of diatom numbers, although the numbers are not in themselves high enough to affect the transparency of the water. The Secchi disc disappeared at a lesser depth after 15th March, when the S.E. trades began and diatom numbers rose. The depth distribution of the diatoms seems, therefore, to depend almost entirely on physical conditions.



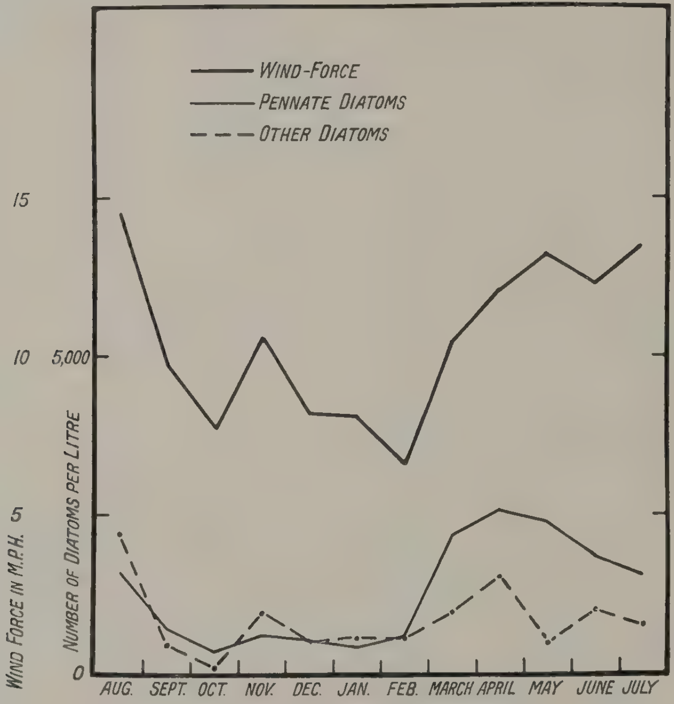
Text-fig. 5.—Secchi disc readings and numbers of diatoms per litre in the surface sample at the weekly station. ——— Number of diatoms. - - - - - Secchi disc readings.

If there was no seasonal variation in the total production of diatoms, neither was there any real seasonal change in the composition of the diatom flora. If the records for individual genera or species (Text-fig. 6) are followed it is seen that they all had much the same distribution. There was a sudden increase in numbers on 31st August, followed by a long period of scarcity, which is broken by the smaller increase on 16th November, in which, however, not all genera took part. Another poor period followed with smaller increases at intervals during December and January, and at the beginning of March the numbers rose definitely and remained higher until July. During the period from December to April the bottom samples were usually richer than the surface samples. Few if any genera were restricted to one season of the year, as is so often the case in temperate waters.



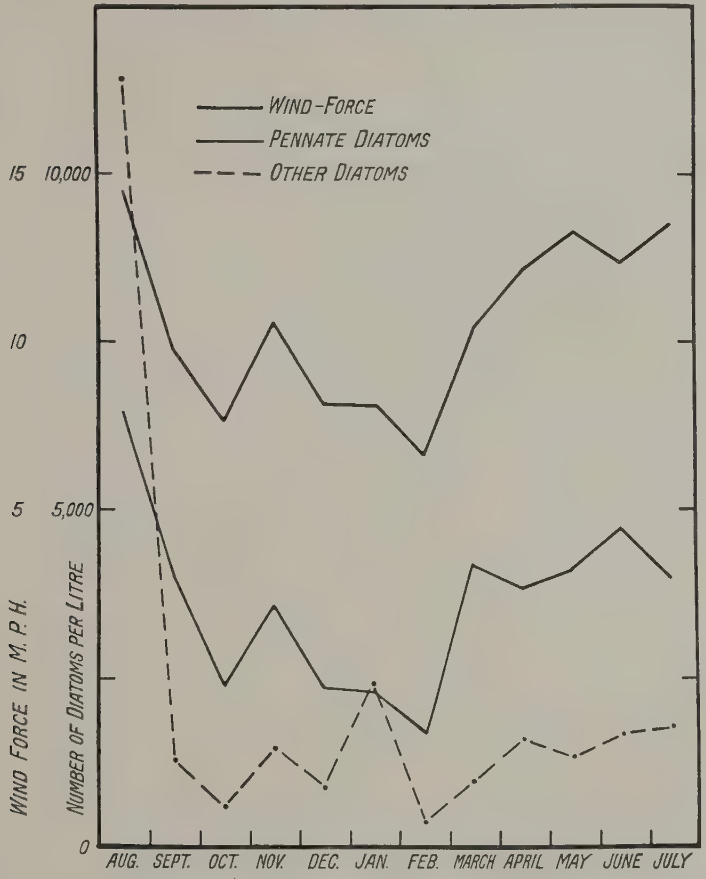
Text-fig. 6.—Distribution of various diatom genera at the weekly station. (a) *Climacodium* spp. (b) *Hemiaulus* spp. (c) *Bacteriastrum* spp. (d) *Rhizosolenia* spp. ——— Surface sample. - - - - - Bottom sample.

On the whole it may be said that plant life (apart from the Cyanophyceae) was poor from the middle of September till the beginning of March—that is, during the warmer half of the year. This is also the calmer half of the year. We have seen that the wind has a considerable effect on the depth distribution of the diatoms, and it seems to affect the total numbers also. In several cases where there was a sharp rise in diatom numbers the station had been worked on, or just after, days of strong wind. Such are 31st August, 16th November, 26th February, 20th April and 14th June. The small increases on 5th and 27th December and 30th January were exceptions. In addition the general and lasting rise in diatom numbers which began between 4th and 15th March coincided exactly with the beginning of the S.E. trades. In the same way September, the month in which diatom numbers gradually decreased, was the month in which the S.E. trades began to slacken. This relation between wind and numbers held also close to the island, although the great fluctuation in numbers from day to day somewhat masked the effect. It is best seen in Text-figs. 7 and 8, where the monthly averages for diatom numbers and wind force are plotted. If the pennate diatoms are plotted separately (Text-figs. 7 and 8) from the others it is seen that, although both curves follow the wind-force to a certain extent, that for pennate diatoms agrees much more closely. This is only to be expected, since many of them are bottom-living forms, which will be stirred up to a greater extent in stormy weather. It must also be noted that after 15th March the pennate forms



Text-fig. 7.—Monthly average number of diatom cells per litre at the weekly station and the monthly average wind-force.

increased to a relatively much greater extent than the non-pennate, whereas in the maxima of 31st August, 16th November and 26th February the reverse was the case, and *Chaetoceros* and other forms showed a relatively greater increase. It is more surprising that the non-pennate forms should have shown a connection with the wind at all. However, the bottom mud contains a good deal of organic matter in process of breaking down (up to 3·74%), and some of this will be stirred up in windy weather to enrich the upper layers.



TEXT-FIG. 8.—Monthly average number of diatom cells per litre in the samples of Series II and the monthly average wind-force.

Other factors which might be expected to influence diatom growth are light intensity, temperature, salinity and concentration of nutrient salts. Full details of these will be found in the hydrographic report by Orr in this volume, to whom I am indebted for all the information about the chemical and physical condition of the sea-water.

Even in the rainiest weather there was so much sunshine that lack of light is not likely to be an important factor near the surface. The water within the Great Barrier Reef lagoon is usually turbid, Secchi disc readings being no deeper than in temperate waters, and the detritus present must shut off a considerable amount of light below the surface.

Verwey (1931) carried out photosynthesis experiments with algae in the Bay of Batavia, and found that the compensation point (*i. e.* the depth at which the light intensity is such that oxygen production just balances oxygen consumption) varied with the Secchi disc reading. When the Secchi disc disappeared at 11 m. (the average depth for the Great Barrier Reef lagoon being 12 m.) the compensation point was at 20–25·5 m. Judging from these results and from those in temperate waters (Gaarder and Gran, 1927 ; Marshall and Orr, 1928 ; Gran and Thompson, 1930), it is probable that photosynthesis could go on almost to the bottom during most of the year. Too much light is also injurious, and this may sometimes affect the surface diatoms.

The beginning of the diatom-poor period in September coincided with the rise of sea-temperature above 25° C., but when diatoms increased again in March the temperature, although beginning to fall, was still near its maximum of 28°–29° C., so that the rise in temperature can have had no depressing effect on diatom production.

The variations in salinity during the year were considerable, and depended mainly on the rainfall. From August to December, 1928, the salinity was usually slightly over 35°/$_{\circ\circ}$, but it then fell abruptly, and this value was reached again only once or twice in July, 1929. This water of high salinity presumably had its origin outside the Great Barrier Reef, and it was characterized by the presence of a number of organisms which were not observed in water inside the Barrier after December. Such organisms were most of the coccolithophores and a few tintinnids. Rainfall might have been expected to influence diatom growth indirectly by bringing down more nutrient salts with the increased outflow from the rivers, but this was not the case. Analysis of the water from the nearest river (Orr and Moorhouse, in this volume) showed that it was poor in phosphate and rich in silicate. Another indirect effect of the rainy season was the temporary stabilization of the sea, but it was not sufficient to allow of the accumulation of nutrient salts in the deeper layers, and so had no effect on diatom growth.

The nutrient salts estimated were phosphate and nitrate, and the amount of these present was always very small. It remained fairly constant during the whole year, however, showing that regeneration was going on at the same time as utilization. The amount of phosphate used up by the small number of diatoms present could not have any effect appreciable by analysis. In temperate waters the number of diatoms during the spring increase rises to about 20,000–40,000 cells per litre before there is an appreciable effect on the pH and the oxygen and phosphate content (Gran, 1930 ; Marshall and Orr, 1927). Even in the richest sample from near the island the diatom numbers rose only to 167,000, and no oxygen or phosphate measurements were made here at this time. At the weekly station 30,000 was the highest figure reached, and it is therefore not surprising that no correlation can be made out between diatom production and chemical constituents. In any case, the fact that utilization and regeneration are going on simultaneously in the same layers would make it almost impossible to disentangle the effects of the different forces at work.

The amount of regeneration depends partly on the breakdown of dead plants and animals, and partly upon the excreta of living animals. In the tropics, where coral makes up a considerable part of the animal community, the latter source accounts for less than would be expected, since coral excreta are mainly utilized direct by the symbiotic algae present (Yonge and Nicholls, Vol. I, Nos. 6 and 7). The symbiotic algae may thus be said to replace part of the phytoplankton.

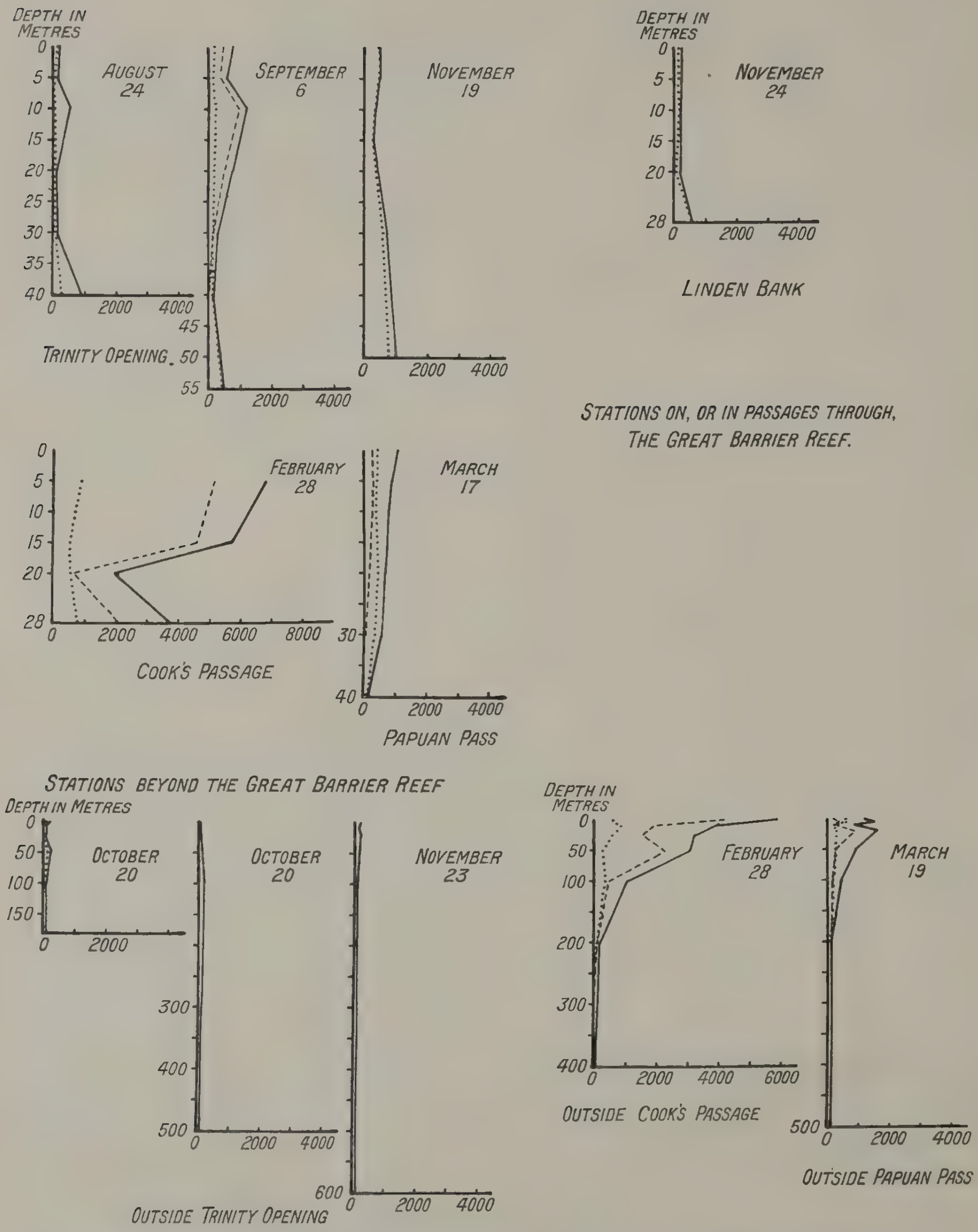
SERIES III (TEXT-FIG. 9 AND TABLE V).

Three visits were paid to Trinity Opening, on 24th August, 6th September and 19th November. Two cruises were made outside Trinity Opening on 20th October and 23rd–24th November. In addition two cruises were made to the north in February and March, one to work stations inside and outside of Cook's Passage, and the other inside and outside Papuan Pass (see Vol. II, No. 1, Plate I for chart of these stations).

The stations in Trinity Opening (Text-fig. 9) were marked on the whole by a greater poverty of plant life than the weekly station. Here, as inside, pennate diatoms made up a considerable proportion of the catch. The station on 6th September came shortly after the big *Chaetoceros* increase of 31st August, and in this case the numbers, although poorer than at the weekly station about the same date, were higher than on 24th August, and *Chaetoceros* was the predominating form. This seems to indicate that the 31st August increase was not merely of local incidence, but happened over a considerable area. In the same way, on 19th November, after the 16th November increase, the numbers were about the same as the weekly station for the same depth, and pennate diatoms predominated.

In the oceanic waters outside Trinity Opening the numbers were always very low, usually under 200 cells per litre. It was, however, at the time when diatoms inside the Barrier were at their scantiest, and the figures for corresponding samples did not differ very much. Below 100 m. they were very low indeed, often less than 50 cells per litre.

Conditions were quite different during the cruises to the north, 26th to 28th February and 17th to 18th March (Text-fig. 9). As has been mentioned already (p. 114), a diatom increase consisting mainly of *Chaetoceros* was going on off Cape Bedford and near Lizard Island, and this increase was found also in and outside of Cook's Passage. Inside Cook's Passage the surface sample was unfortunately lost, but there was a maximum of nearly 7000 cells per litre at 5 m., and even at 20 m. there were over 2000. *Chaetoceros* predominated at all depths. In the oceanic waters outside the Passage there were nearly 6000 cells per litre at the surface, over 3000 at 50 m., 1000 at 100 m. and 100 at 200 m. *Chaetoceros* was the predominating form except at and below 200 m., where pennate forms predominated. The phosphate content of the water was high at and below 200 m., but at 100 m. and in all samples above that it had fallen to a low value—much the same as that usually found in inside waters. Photosynthesis may go on much deeper in the clear waters outside the Barrier, but on this occasion the Secchi disc reading was only 14 m. The presence of the diatoms may partly, but certainly cannot entirely, account for this. Ten days later, on 8th March (Station 47A), a single sample was taken from the surface at approximately the same position (kindly obtained for me by Dr. C. M. Yonge on his dredging cruise) and it still contained a large number of diatoms—more than 6000 cells per litre. The composition of the sample had changed, however; pennate diatoms formed nearly one-half of the whole number, and *Rhizosolenia* spp. were almost as abundant as *Chaetoceros*. Increases inside the Barrier never lasted for as long as this, which can, perhaps, be correlated with the fact that there was an upwelling current where the deep water struck against the steep bank of the Barrier. This current probably brings up nutrient salts from deep water, which are thus made available for diatom growth in the surface waters.



Text-fig. 9.—Depth distribution of diatoms (number of cells per litre) at the stations outside or in passages through the Great Barrier Reef. ——— All diatoms. - - - - - *Chætoceros*. . . . . . . Pennate diatoms.

The stations in and outside of Papuan Pass were worked on 17th and 18th March (Text-fig. 9). This was just after the beginning of the S.E. trade and the general rise in diatom numbers inside the Barrier. Both in the Pass and outside it the numbers were considerably lower than at the weekly station at the same time, but were higher than any found outside Trinity Opening. Outside there were over 1000 cells per litre at the surface, about 800 at 50 m. and 400 at 100 m. Below this the numbers were negligible. A sample was taken from a depth of 100 m. closer to the reef, on the 100-fathom line, and the number of diatoms in it was only 45 per litre, thus agreeing with the samples taken at 200 and 500 m. further out. It is impossible to base conclusions on such low figures, but it is an interesting confirmation of the upwelling of the deep-water layers near the reef which is indicated by the hydrographic results. In the Pass numbers were about 1000 per litre at the surface, and fell gradually to 200 per litre at 40 m. At both stations *Chaetoceros* and pennate diatoms were the most important forms, *Chaetoceros* being more abundant outside. *Rhizosolenia* and *Bacteriastrum* were also numerous. A single surface sample taken on 27th April outside Palm Passage on the Willis Island cruise (Station 58 A) contained 300 diatoms per litre, in which *Rhizosolenia* and pennate diatoms were present in equal numbers with only a few other forms.

The number of stations worked in oceanic waters outside the Barrier Reef is too small to afford any definite conclusions about the relation of the plankton outside to that inside the Barrier. Conditions are further complicated by the fact that the stations outside Trinity Opening were worked at a time of year generally poor in diatoms, and are slightly poorer than corresponding inside samples, whereas the stations to the north were worked during or soon after a diatom increase, and the samples are almost as rich as those inside. The end of August and mid-November increases had apparently far less influence on the waters in Trinity Opening and outside it than the end of February increase had on the waters in and outside Cook's Passage. In spite of this, the hydrographic conditions of the water inside and outside Trinity Opening in November and December resembled each other more closely than did those of the water inside and outside Cook's Passage in February. Another interesting feature is that in outside waters, when diatoms were rich, the greatest numbers were found at the surface. The large proportion of pennate diatoms even outside the Barrier is surprising, but is probably due to the proximity of the reefs.

DINOFLAGELLATES.

Series I and II (Tables III and IV).

Dinoflagellates occurred throughout the year in varying numbers (Text-fig. 3). They were not so numerous as diatoms, except when the numbers of the latter fell very low. They were always more abundant near the island than at the weekly station. There the numbers were almost always highest at the surface. The great majority of these dinoflagellates belonged to the minute naked *Gymnodinium* spp. The numbers at the weekly station were highest in August, varying from 200–1000 per litre in the surface layer, decreased gradually during September, and reached a very low value in October. During November and December the numbers were slightly higher, and on two occasions reached a figure of about 1000 per litre. This was the maximum figure for the year, and was reached only three times—on 16th August, 6th November and 19th December. The numbers were again very low in January, slightly higher at the surface in February, and very low in March and April, after which they increased again.

The numbers near the island were, as has been stated, higher than at the weekly station, and numbers of over 1000 per litre were not uncommon except during March, April and the first half of May. Numbers from 1800 to over 2000 per litre occurred several times in August, once each in September, in November, in December and in January not at all from February to June, and once in July. The course of events was more or less the same as at the weekly station, but the dates of increases did not correspond. This is not surprising, since there was much fluctuation of numbers from day to day. The thecate forms, if considered separately (Text-fig. 3), were found to have much the same distribution, although always less numerous. The commonest forms were small *Ceratium* spp., particularly of the *C. furca* type. The genus *Amphisolenia* is apparently an exception, since it is almost restricted to the months from January to July or August. Apart from a few scattered records, it was not seen till 30th January. It then occurred frequently in both tow-nettings and water samples until July, with a maximum from April to June.

The extremely low numbers in October, March and April did not correspond to any climatic change, nor did they coincide with the period of diatom poverty. March and April were stormy months, but August, when dinoflagellates were richest, was equally so. Their occurrence gives no support to the hypothesis that an increase in dinoflagellate numbers is related to conditions of high temperature and low salinity (Marshall and Orr, 1927).

SERIES III (TABLE V).

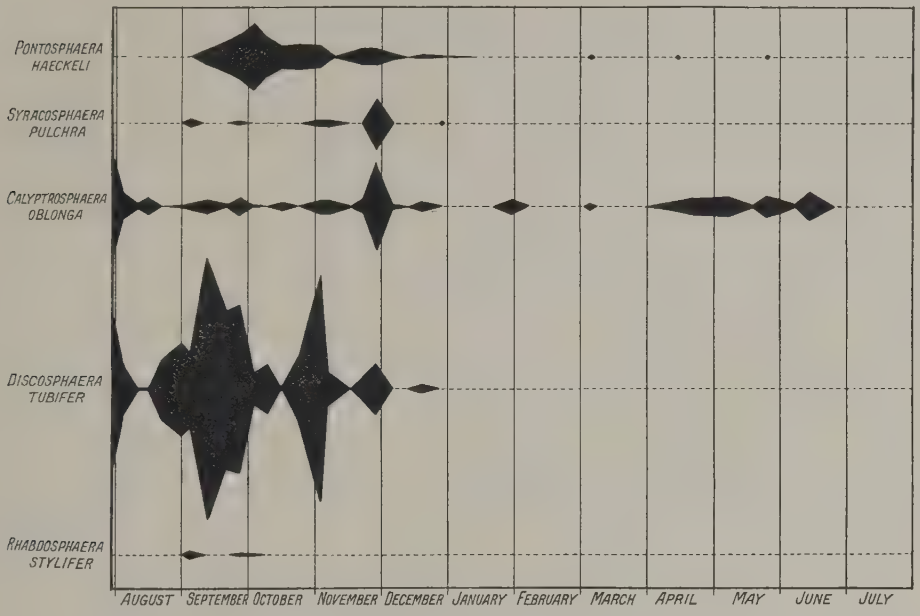
In many cases the samples from Series III had to be preserved before examination, and so most of the small naked forms which make up the bulk of the dinoflagellates were lost. Those from Trinity Opening and outside it were usually examined fresh, and their content of dinoflagellates was very much the same as that of samples from the weekly station about the same date.

Those from the cruises to the north were all fixed except for the surface samples, which were considerably poorer than corresponding samples from the weekly station. The surface sample outside Papuan Pass was the only exception.

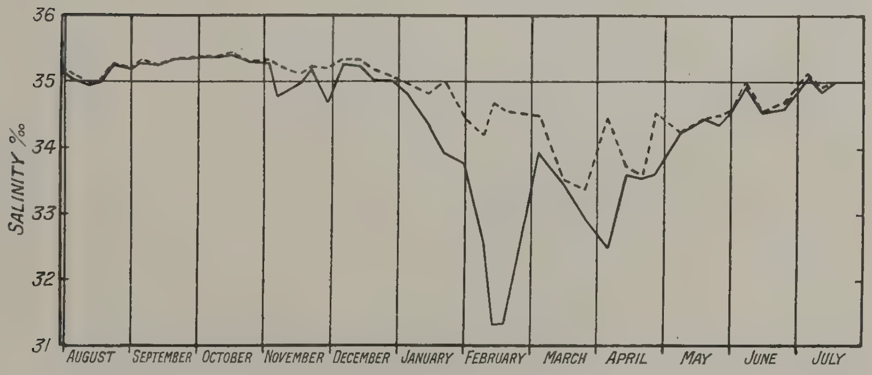
OTHER GROUPS.

The coccolithophores (Text-fig. 10) were never numerous, and were least so near the island. The highest numbers were found in and outside Trinity Opening. In the lagoon channel they were almost entirely restricted to the months from July to December. *Calyptrosphaera oblonga* Lohmann appeared several times from January to March, and occurred frequently from April to July; there were also scattered records of *Pontosphaera haeckeli* Lohmann up till May, but the other coccolithophores disappeared completely after December and were not seen again. The majority of the samples taken from outside the Barrier in February and March had to be preserved, but in the surface samples examined fresh there was only one coccolithophore seen, a *Calyptrosphaera*. It would seem, therefore, that they had decreased or disappeared outside the Barrier as well as inside. While present, *Discosphaera tubifer* Murray and Blackman was the most abundant species. Its numbers rose several times to 200 per litre, and in Trinity Opening to 240. The other species were scarcer, and their numbers were rarely above 50 per litre.

At first sight this appears like a true seasonal variation, but if we examine the hydrographic conditions we find that up till the end of December the salinity of the water both inside and outside of the Great Barrier Reef was 35°/$_{\circ\circ}$, or a little above that (Text-fig. 11). It is well known that coccolithophores are, for the most part, oceanic in habitat, and that they appear to be restricted to water of a relatively high salinity. *Calyptrosphaera oblonga* is the only exception, and apparently adapted itself to more neritic conditions. After



TEXT-FIG. 10.—Seasonal distribution of coccolithophores at the weekly station. Total numbers in samples from all depths.



TEXT-FIG. 11.—Salinity (in parts per thousand) in the surface and bottom samples at the weekly station.

the rainy season was over the salinity began to rise again, but it did not reach 35°/₀₀ again till July, and then only occasionally. Even outside the Barrier on 28th February and 17th March the salinity was below 35°/₀₀. In the Norwegian Sea also Gran (1929) has observed that where the salinity falls below 35°/₀₀, coccolithophores (in this case *Pontosphaera huxleyi* Lohmann) give place to diatoms. The proportion of oceanic water to coastal water in the Great Barrier Reef lagoon probably varies from year to year, and on this will depend the abundance of coccolithophores.

The numbers of most of the other protozoa were too small to give much idea of seasonal distribution. Silicoflagellates, Amoebae, Radiolarians and Foraminiferans were all recorded occasionally throughout the year. Tintinnids were more numerous, and although species varied a little, they seemed to be commonest in August and after March. The genera *Leprotintinnus*, *Tintinnopsis* and *Codonellopsis* are neritic in habitat, and were more evenly distributed throughout the year. Two genera, *Rhabdonellopsis* and *Xystonella*, are definitely oceanic, and were found only outside the Great Barrier Reef and at the weekly station in August and September, when the salinity was high. *Dadayiella ganymedes* (Entz Sr.) was very rare till in November and was then present for the rest of the year, and *Dictyocysta* was present only from March onwards, but there is not enough evidence to show whether these genera were restricted by any conditions of temperature or salinity.

The Cyanophyceae are a widely distributed group, but from the nature of their growth habits it is not to be expected that their numbers will be accurately reflected in the water samples. Very often the sea surface was covered with large red patches of *Trichodesmium* in one place, while a few miles away the surface might be apparently free from it. These surface accumulations were naturally most often seen in calm weather, and were not seen after the trade winds began in March. Near Low Isles they were most abundant in the end of August, 1928, when large patches drifted on to the reef, caused distress to the fish in the moats, and eventually decayed along the shore. According to notes made by Mr. F. S. Russell at the time, this stranding of the algae on the shore went on from 22nd to 25th August, and at the same time thick patches were visible on the sea surface near Low Isles. The strong winds at the end of August dispersed these accumulations and washed the decaying algae from the shore. They never reappeared to the same extent, but red patches were visible on the sea surface at intervals during September, October, November and December. In the water samples the occurrence of *Trichodesmium* was irregular, but it was most numerous during the calmest months, November to February. The number of threads was counted, and each thread contained a large number of cells, the average number for a thread being estimated by Lohmann (1920) at 80. The depth distribution was also irregular, and cannot be correlated with that of the diatoms, or (apart from the fact that they were more numerous in calm weather) with that of any physical condition. When we consider that each of the threads contains up to 100 cells, it will be seen that, in summer at least, the cyanophycean cells frequently outnumber those of any other group. This is in accordance with their well-known importance in tropical plankton (Lohmann), but they have apparently no measurable effect on the chemical composition of the sea-water.

Metazoa did not appear in the water samples to any considerable extent. Copepod nauplii were the most abundant forms, and occurred throughout the year at all depths. They were more numerous during the summer, from the middle of November to the middle of March, than during the rest of the year.

DISCUSSION.

In comparing the quantity of phytoplankton in the Great Barrier Reef region with that from elsewhere, the most striking fact is, of course, that there is little seasonal variation either in the numbers or in the specific composition of the microplankton.

During the cruise of the " Deutschland " across the Atlantic in 1911 Lohmann (1920), made a long series of observations on the microplankton, and came to certain conclusions about the differences between temperate and tropical waters. Some of the conclusions are not applicable to the present work, since he was dealing mainly with oceanic, as compared with coastal water, but some of them are confirmed.

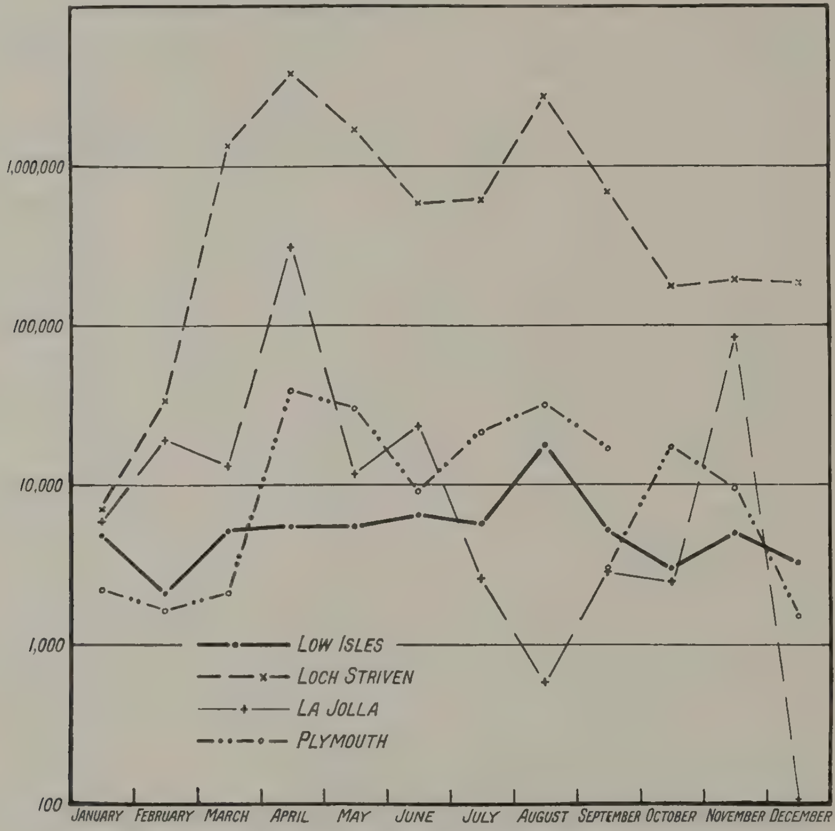
Of all the groups present, the Cyanophyceae, and especially *Trichodesmium*, which is almost confined to the tropics, is the only one which is more abundant in tropical than in temperate waters. Lohmann found that in the tropics the number of organisms per litre could be reckoned in thousands, in temperate oceanic water in tens of thousands, and in temperate coastal water in hundreds of thousands. The average number of organisms per litre in the tropics—a few thousand—agrees fairly well with the present findings although the Great Barrier Reef waters are not oceanic but coastal.

The constitution of the samples in the open ocean is, however, very different. As the tropics are approached the percentage of diatoms in the samples falls from 60 or 80% to under 5%, while the percentage of coccolithophores and dinoflagellates rises until either may form 40 or 50% of the total number of organisms. In a narrow region of the tropics, to the north of the equator, *Trichodesmium* may form up to 60%.

In the samples from the Great Barrier Reef region diatoms were almost always predominant over all forms other than *Trichodesmium* cells. Only during November, and in a few samples from Trinity Opening and outside it, were dinoflagellates more abundant. Coccolithophores, except in a few samples from Trinity Opening and outside it, never formed an important part of the catch. These differences must be attributed to the coastal influence of the coral reefs. The composition of the microplankton in the lagoon of the Great Barrier Reef, therefore, depends partly on the amount of oceanic water which has come in from outside the Barrier, but the extent of this outside influence and its variations from year to year can only be discovered by further work.

Another important point in which Lohmann's results differ from the present is in the depth distribution. Whereas in temperate waters he finds the maximum abundance at the surface, in the tropics (if the Cyanophyceae be excepted) it lies at a depth of about 50 metres. As has already been explained, the depth distribution of the phytoplankton from the Great Barrier Reef lagoon is mainly determined by the physical factors, such as wind, but a few samples were taken from deep water outside the reef. When diatoms were poor, the numbers were too small to be significant and the depth distribution was irregular, but on the two occasions when they were numerous (Text-fig. 9) the maximum lay at or near the surface (p. 125). It is stated (Sleggs, 1927) that off the coast of California also the maximum abundance of diatoms is found below 25 m. Conditions along that coast are, however, greatly influenced by the upwelling of water rich in nutrient salts. The surface waters, according to Moberg (1928), are always denuded of nutrient salts, and production goes on to the greatest depth at which photosynthesis is possible. The depth of the diatom maximum depends, then, on the rapidity of upwelling. The work which was done outside the Great Barrier Reef indicated that upwelling took place there, at least at certain times of the year. It would be interesting to discover to what extent it goes on throughout the year, and what influence it has on plant life.

Hitherto no continuous work has been done on the phytoplankton in tropical waters, but it is possible to compare the production of diatoms there with that of various places in the temperate zone (Text-fig. 12 and Table I). The Scripps Institute at La Jolla, California (lat. 33° N.), has carried on an investigation of the phytoplankton for a number of years, and it is the nearest station to Low Isles, from the point of view of latitude, at which such work has been done (Allen, 1927, 1928). Their method of working is not the same, since the samples are filtered through bolting silk, and are then preserved and an aliquot portion counted. The samples are drawn from the surface close to the shore at various places along the Californian coast—La Jolla, Point Hueneme, Oceanside and others—and the results can therefore be compared most readily with those of Series II taken close to Low Isles. The seasonal variation in the Californian samples is less marked than in waters further north, for, although the main period of production is usually during the



Text-fig. 12.—Monthly averages of diatom numbers per litre at various stations for comparison with Low Isles.

second quarter of the year, this is not invariably the case, and a time of high production may occur in any quarter. It probably depends as much on the supply of nutrient salts by upwelling as on any seasonal change. The actual numbers of diatoms are, as a rule, higher than those for Low Isles samples. Only in years of poor production, such as in 1925 at La Jolla and Oceanside (Buley, 1929) and in 1926 at all Californian stations (Fox, 1929), do the Low Isles figures rise above them for most of the year.

TABLE I.—*Monthly Average Number of Diatoms at Different Stations.*

Month.	Low Isles, Series I, 1928–29.	Plymouth, 1915–16.	Loch Striven,* 1926.	Kiel Bay, 1905–06.	La Jolla, 1922.
January	4,750	2,190	7,000	4,100	5,920
February	2,070	1,620	34,000	4,800	19,170
March	5,180	2,070	1,356,800	48,000	13,310
April	5,440	38,560	3,792,200	850,000	312,510
May	5,470	30,420	1,686,900	2,100,000	11,770
June	6,390	9,120	585,500	2,480,000	23,220
July	5,780	21,390	620,900	37,000	2,650
August	17,810	31,780	2,774,900	130,000 (44,000)	590
September	5,310	17,110 (2,990)	693,650	1,400,000	2,880
October	2,990	17,410	179,000	440,000	2,530
November	5,040	9,500	196,000	15,000	85,290
December	3,280	1,500	186,000	8,500	110

Centrifuged water samples were counted at Plymouth (Lebour, 1917) from a position outside the breakwater, 2½ miles from shore. Seasonal variation is well marked, with spring and autumn or late summer maxima and a winter minimum, and it is only during the latter, in the months December to March, that the Low Isles figures are higher. During the rest of the year they are from two to ten times lower.

In enclosed waters further north, such as the Scottish sea lochs, the Norwegian fjords and Kiel Bay, conditions are still more favourable for diatom growth. In Loch Striven in the Clyde Sea-area (Marshall and Orr, 1927) there is a great increase in early spring, during which the diatom numbers may rise as high as 25,000,000 cells per litre, and this is followed by a series of increases during the summer, which are usually less than the spring increase. These summer increases are determined by a mixing of the surface layers with water from greater depths rich in nutrient salts. The monthly averages during the unproductive winter months, December, January and February, are always above those for Low Isles, although individual samples may occasionally have a lower diatom content. Lohmann studied the plankton at Laboe in Kiel Bay during 1905 and 1906 (Lohmann, 1908), and his results are given in Table I as monthly averages. His figures are very high—higher than anywhere except Loch Striven. The area in which he worked is known to be subject to contamination from land drainage, and this probably accounts for its richness in plankton.

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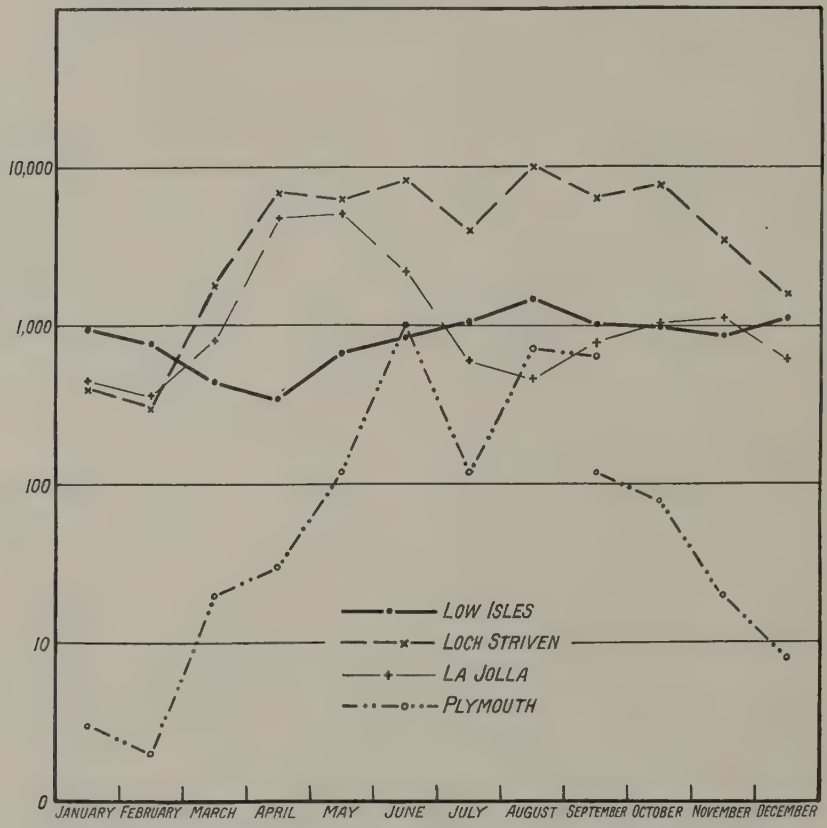
* The number of chains of diatoms counted has been multiplied by 10 to give figures comparable with the other stations, where diatom cells were counted.

If we compare the number of dinoflagellates at these different places we find that very much the same holds good (Text-fig. 13 and Table II). At Low Isles the dinoflagellates are more numerous during times of low production and less numerous during times of high production than off the coast of California. It must, however, be remembered that the Californian samples are preserved, and that thereby a large number of naked forms (the forms which are usually most numerous in the Low Isles samples) are undoubtedly lost. Plymouth figures are very much lower, and the monthly average is almost always only a small fraction of the Low Isles figure. Loch Striven, on the other hand, is much richer in dinoflagellates during most of the year ; only in January and February do the figures there fall below those for Low Isles. At Laboe the dinoflagellates are very numerous (Table II), and the figures are much higher than for any other place.



Text-fig. 13.—Monthly averages of dinoflagellate numbers per litre at various stations for comparison with Low Isles.

TABLE II.—*Monthly Average Number of Dinoflagellates at Different Stations.*

Month.	Low Isles, Series I, 1928–29.	Plymouth, 1915–16.	Loch Striven, 1926.	Kiel Bay, 1905–06.	La Jolla, 1922.
January	960	3	400	7,000	460
February	780	2	300	4,800	360
March	450	20	1,800	16,000	820
April	350	30	6,940	18,000	4,770
May	680	120	6,250	31,000	5,140
June	860	1,020	8,240	187,500	2,230
July	1,060	120	3,960	382,000	600
August	1,470	730	10,000	146,000 (105,000)	470
September	1,020	120 (640)	6,400	19,000	790
October	970	80	7,700	6,600	1,040
November	860	20	3,430	14,000	1,130
December	1,110	8	1,600	7,400	600

Although in Text-figs. 12 and 13 the curves given are for one year only, in the case of the Clyde Sea-area and Californian samples we have several years' results with which a comparison can be made. In the former case the figures for different years do not vary much and are always very high, but in the latter one year may differ considerably from another, and an average year has been selected for reproduction. Only one year's figures are available for Plymouth and for Low Isles, so it is possible that the year investigated might prove not to be an average year.

It is possible to get some idea of the differences between the various places by comparing the number of diatoms and dinoflagellates per day, averaging from the whole year (Text-fig. 14). This can, however, give only a very rough idea of the real differences, since it ignores some of the essential factors influencing diatom growth. In the tropics, for instance, the higher temperature must increase metabolism, so that the life-cycle will be completed more rapidly and the number shown will be relatively too low. It has already been shown (p. 113) that any change—for example, an increase in the number of diatoms—appears and disappears much more rapidly than in temperate waters.

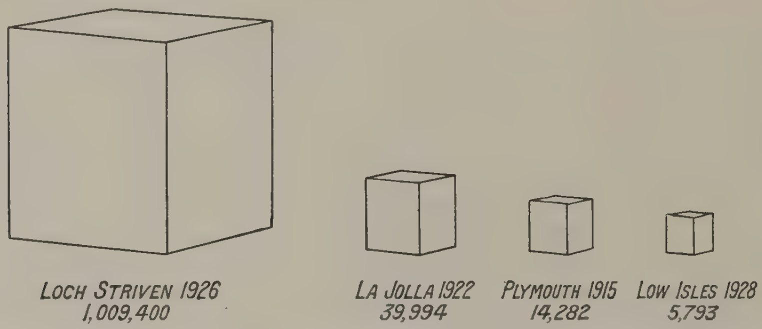
Quantitative estimations of microplankton, particularly diatoms, have been carried out in many other places for a short time only, or during the course of periodic cruises, and it is of some interest to compare the figures thus obtained with those from Low Isles. In most cases the investigation has been in areas where plankton production is discontinuous, and the figures vary very much from season to season, and even from place to place in one season.

Thus, during the survey of plankton production in North European waters in the spring of 1912 (Gran, 1912), the spring diatom increase was in progress in February in the Skager Rak, and there were from 200,000 to 915,000 diatom cells per litre in the richest samples. In June at the same station the numbers had fallen to a few thousand per litre. In the North Sea in May and June conditions were very different in different places. At the east end of a section across the entrance to the Norwegian Sea diatoms were very scarce, and as few as 20 per litre were found in some samples, whereas towards the west end of the same section the numbers rose to 2,000,000 per litre. The same variation was found in the southern part of the North Sea.

On the west coast of North America, where conditions are much affected by the upwelling of deep water rich in nutrient salts, similar great fluctuations have been found (Bigelow and Leslie, 1930; Gran and Thompson, 1930).

On the whole it may be said that when samples are taken during a diatom increase figures rise far above those for Low Isles; when they are taken during a period of diatom poverty, figures are sometimes about the same, and sometimes below those for Low Isles.

One great difference between conditions in the Great Barrier Reef lagoon and those hitherto studied is the lack of stability in the water layers at any time of the year. During the wet season stabilization occurred to a certain extent, but although there was a gradient from top to bottom in both temperature and salinity, the temperature continued to rise and the salinity to fall throughout the whole depth (Orr, Vol. II, No. 3). In summer, in temperate waters there is a layer of warm water overlying the deep colder water, and this allows an accumulation of nutrient salts to take place in the deeper layers, which is only brought up to the surface in autumn. It is not utilized at once because of the winter darkness and turbulence, and is therefore available in early spring for an enormous increase in plant life. The water is stripped of nutrient salts to a depth almost as great as that to which photosynthesis can go on, and growth then stops until a fresh supply is introduced. Thus one can obtain an approximate figure for the amount of phosphate, nitrate, etc., used up in each increase. This is not possible in an area where production and regeneration are going on simultaneously.



TEXT-FIG. 14.—A comparison of the daily average number of diatoms at different places, expressed as cubes (see Table I).

Such an area in temperate waters has been described (Ostenfeld, 1913) in the Limfjord in Denmark. Here the water is shallow enough for vertical circulation to go on daily throughout the year, and there is a plentiful supply of nutrient salts from land drainage. A rich diatom plankton is consequently found all the year except during the darkest winter months. Low Isles differs from this mainly because the supply of nutrient salts (coming, not from land, but by regeneration from the bottom) is small and can maintain production only at a very low level. There is, of course, no cessation of production during any part of the year on account of light conditions.

It is probable that this kind of plankton production is typical of many shallow coastal waters in the tropics. Wherever there is a steady wind (as in the region of the trades), and the water is shallow enough for this to cause a constant vertical circulation, and wherever there is no outside source of nutrient salts, such as upwelling, diatom production will depend on the regeneration which goes on from day to day, and diatom numbers are likely to keep fairly constant all the year round.

I have much pleasure in thanking other members of the Expedition, especially those of the boat party, for help in collecting and in centrifuging water samples. I am also indebted to Mr. A. G. Nicholls for the wind records.

This work was done during the tenure of a Carnegie Research Fellowship, and I wish to express my gratitude to the Trustees for their assistance.

SUMMARY.

Water-samples from the lagoon within the Great Barrier Reef have been examined and the organisms in them counted throughout a year.

Diatoms predominate except in a few cases, and among the diatoms, pennate forms are most abundant.

The number of diatoms remains comparatively constant throughout the year; there are no great increases, such as occur in temperate waters. The depth distribution of the diatoms depends largely on physical conditions. There is no real seasonal cycle of diatom growth; such small increases as did come were apparently correlated with strong winds, which may have stirred up nutrient material from the bottom. The nutrient salts estimated were present only in very small quantities throughout the year, and no relationship can be made out between them and diatom abundance.

Samples were also examined from passages through the Great Barrier Reef and from the oceanic water outside it. They were usually poorer in organisms, but resembled the samples inside in general composition.

Dinoflagellates occurred throughout the year in varying numbers, but their abundance could not be correlated with any of the chemical or physical factors examined.

Of the other groups Cyanophyceae are the most abundant, but are irregular in their occurrence, appearing mainly in the calmer half of the year (September to February). Coccolithophores and some tintinnids are restricted by salinity conditions, and are found only in water with a salinity of 35 parts per thousand or more. Such water is found inside the Barrier only at certain times of the year.

The results of this work in the Great Barrier Reef region are compared with those from similar work elsewhere.

It is concluded that the type of plankton production found (*i. e.* the numbers low, and varying little during the year) depends on the physical conditions. The constant winds keep the shallow waters of the Great Barrier Reef lagoon stirred up from top to bottom all the year round, so that there is no opportunity for an accumulation of nutrient salts in the bottom layers. Regeneration and utilization of these salts therefore go on continuously throughout the year, and plankton production is kept at a low but fairly constant level.

PART II

NOTES ON ORGANISMS.

The following notes are meant to supplement the more general account given in Part I. They are compiled from the records of water samples of Series I and II in Tables I and II, with the addition of notes from the Apstein net hauls at the weekly station. The former give a more accurate estimate of the small forms which are not quantitatively caught by the net, but some of the larger organisms (*e. g. Amphisolenia*, *Pyrophacus*, and the large Tintinnids) occur so rarely in the water samples that their distribution is best seen from tow-nettings.

DIATOMS.

Paralia Heiberg.—Occurred in small numbers throughout the year, but was commonest from March to August. This is a genus which is most frequent in the bottom layers (Ostenfeld, C. H., 1914), and will most readily be stirred up in the windy weather of these months.

Skeletonema costatum Greville.—Rare. It appeared occasionally in October and November, and again in April, May and June. This species has an exceedingly wide distribution in coastal waters. It has been recorded from the Sandwich Islands, Japan, Siam, the Malay Archipelago, the Bay of Bengal, the Mediterranean, Aral, Caspian and Black Seas and Vladivostok Bay. It is one of the most abundant species on North European coasts and is abundant also in the Gulf of Maine. It is listed as one of the five most important diatoms on the Californian coast, and has been noted as occurring in large numbers off Ceylon.

Thalassiosira Cleve.—Appeared from November onwards, but was never common.

Hyalodiscus (Ehrenberg).—Occasional throughout the year.

Coscinodiscus (Ehrenberg).—Present in small numbers throughout the year, and, like *Paralia*, least numerous in the calm months from September to February.

Planktoniella Schutt.—Rare, and mainly found at stations outside the Great Barrier Reef. An oceanic genus widely distributed in warm water.

Asteromphalus Ehrenberg.—Occasional throughout the year, and, like *Paralia* and *Coscinodiscus*, was most numerous in and after March.

Rhizosolenia (Ehrenberg) Brightwell (Text-fig. 6).—Occurred throughout the year in comparatively large numbers. It was common in August, its numbers rising to a maximum on 31st August. After this it decreased and took little part in the 16th November increase. Its numbers rose again in and after March. The species of the *R. stolterforthii* H. Peragallo type (*i. e.* those whose cells are united to form spiral coils) were counted separately and showed the same distribution, although almost always less numerous. Lohmann (1920) found *R. stolterforthii* absent in the tropics except off the coast of Pernambuco, and concludes that, although it is widely distributed over the oceans in very small numbers, it can only develop under favourable conditions.

R. robusta Norman and *R. styliformis* Brightwell were common at times. Many of the larger *Rhizosolenia* spp. were infected with the parasitic *Richelia intercellularis* Schmidt.

Corethron Castracane.—Very rare. Appeared singly in July, October, December, March and April.

Bacteriastrum Shadbolt (Text-fig. 6).—Usually present except in September and October. Most numerous on 31st August, 16th November, and after December. This is a diatom characteristic of neritic conditions. Several species occurred.

Chaetoceros Ehrenberg.—Increased during August until 31st August, when it was the most important form; decreased in the last half of September, and remained poor till December, except for the outburst on 16th November, in which it took an important but not a predominant part. After December it had numerous small increases and was most abundant from March to July. A large number of species occurred.

Hemiaulus Ehrenberg (Text-fig. 6).—Frequent in August, being most numerous on 31st August. After this it was scarce, except on 16th November, until the end of January, when it became numerous again. *H. hauckii* Grun. and *H. indicus* Karsten, both tropical oceanic species, were the commonest forms.

Climacodium Grun. (Text-fig. 6).—Except for small increases in August and October it was rather scarce until December. It was always present after that. *C. biconcavum* Cleve was the predominant species. *C. frauenfeldianum* Grun. was much less common but occurred frequently after December.

Cerataulina H. Peragallo.—Scarce, except for small increases in August and on 16th November, until the end of November. After this it was frequent though never abundant.

Biddulphia Gray.—Present occasionally throughout the year, most commonly from March to August.

Lithodesmium Ehrenberg.—Occasional.

Ditylium sol Van Heurck.—Occasional.

Pennate Diatoms.—These have been dealt with fully in Part I. Forms of the type of *Nitzschia closterium* (Ehrenberg) were counted separately to see whether the distribution of one species varied much from that of the whole group, but there was no significant difference.

Leptocylindrus sp.—This diatom occurred in two forms, similar except for size. The narrow form with cells 13μ wide and 65–108μ long appeared in large numbers on 31st August, and was present occasionally afterwards. The wide form with cells 21μ wide and 39μ–60μ long was frequent after December.

Dinoflagellata.

Exuviella Cienkowski.—Rare from September to April, occasional during the other months.

Prorocentrum Ehrenberg.—Occasional throughout the year, usually singly.

Pronoctiluca pelagica Fabre-Domergue.—Although Lohmann (1920) lists this species as typically oceanic, it occurred throughout the year in small numbers, more frequently near the island than at the weekly station.

Amphidinium Claparède and Lachmann.—Occurred all the year round in small numbers, but was scarce at the weekly station after December.

Gymnodinium Stein.—Always present in considerable numbers, forming the bulk of the dinoflagellates. Most of them were of the minute *G. simplex* type. The chromatophore-bearing forms were always much less numerous than the colourless.

Gyrodinium Kofoid and Swezy.—Occasional throughout the year in small numbers.

Cochlodinium Schutt. Occasional throughout the year in small numbers, but a little more numerous than *Gyrodinium.* One of the commoner forms was *C. pulchellum* Lebour.

Pouchetia Schutt.—Occasional throughout the year in small numbers. The usual form was small with the ocellus not well developed. When they were examined they had usually lost the flagella, and the girdle and sulcus had disappeared, so that it is possible that they were really *Protopsis*, Kofoid and Swezy.

Nematodinium Kofoid and Swezy.—Occurred once on 15th September near the island. It was small, and possibly belonged to *N. armatum.*

Phalacroma Stein.—Frequently present in small numbers up to November, afterwards scarce.

Dinophysis Ehrenberg.—Appeared only at intervals throughout the year. *D. caudata* Kent was the most frequently occurring species.

Ceratocorys Stein.—Occasional throughout the year.

Ornithocercus spp.—Occasional throughout the year.

Amphisolenia bidentata Schroder.—Rare until January, after which it appeared occasionally. It was frequent from April to July. This species has a world-wide distribution in tropical and warm temperate seas.

Gonyaulax Diesing.—Appeared occasionally throughout the year.

Diplopsalis Bergh.—Occurred frequently in small numbers throughout the year.

Peridinium Ehrenberg.—Present all the year round, although never in large numbers: 60 per litre was the highest figure reached at the weekly station, and 120 per litre near the island.

Pyrophacus horologicum Stein.—Occurred only very rarely in the water samples, but was usually present in the tow-nettings from August to April, being commonest in August, December and January. All specimens observed had 7 apical and 3 antapical plates, with 12 pre- and post-cingulars, thus agreeing with the form described by Stein (1883). Specimens measured 150 by 125μ. This species has a wide distribution in the warm waters of the oceans. It seems probable that the smaller form described by Lebour (1925) as occurring in the English Channel and the Baltic, which has only 9 pre- and post-cingulars, is really a different species.

Oxytoxum Stein.—Frequent all the year round. The majority of specimens were small, but *O. scolopax* Stein appeared occasionally.

Ceratium Schrank.—One of the most abundant genera and occurred all the year round. Several species of the subgenera *Biceratium* and *Amphiceratium* occurred. The species belonging to the subgenus *Euceratium* were separated into those with the tips of the antapical horns closed (*C. tripos* type) and those with them open (*C. macroceros* type).

Subgen. *Biceratium* (Vanhöffen) Gran. *C. candelabrum* (Ehrenberg).—Rather rare, occurring in September, October, February and March.

C. kofoidii (Kofoid and Swezy) Jörg.—The commonest species occurring. It was present throughout the year—although scarce from December to April. Most abundant in August and again in June and July. The highest number present at the weekly station was 60 per litre in July, 1929, and August, 1928, and near the island 170 per litre on 28th August.

C. furca, probably subspecies *eugrammum* (Ehrenberg). A more stoutly built species. It was much less numerous than the preceding, but had the same distribution.

C. teres Kofoid, *C. pentagonum* Gourret, and possibly *C. setaceum* Jörg. were counted together. They were present in about the same numbers as *C. furca* up till November, after which they were scarce.

Subgen. *Amphiceratium* (Vanhöffen) Gran. *C. fusus* (Ehrenberg) Dujardin.—Occurred in small numbers throughout the year, but was most numerous in May, June and July.

C. pennatum Kofoid.—In this species the right antapical horn is present as a small spine and the left horn is slightly bent at the end. This species was less common, and was found only occasionally throughout the year. It was rare or absent from mid-November to March.

C. extensum Gourret.—A very long, slender form, more than 1 mm. in total length. It was taken several times in tow-nettings.

Subgen. *Euceratium* Gran. *C. tripos* type.—Present throughout the year in small numbers, scarcest from December to March. Less common near the island than at the weekly station.

C. macroceros type.—As *C. tripos* type, but more numerous during the summer months. Also commoner at the weekly station than near the island.

It may be noted that the *Ceratium* species which have been identified are all recognized as oceanic forms with a wide distribution.

Podolampas Stein.—Occurred in small numbers throughout the year.

Blepharocysta splendormaris Ehrenberg.—Occurred throughout the year in small numbers.

Unidentified thecate forms, both brown and colourless, were present throughout the year in small numbers. They were scarcest in January, February and March.

COCCOLITHOPHORAE.

Pontosphaera haeckeli Lohmann.—Present in almost all samples from all depths at the weekly station from September to the end of November. After this there were only scattered appearances. The highest number recorded was 60 per litre in Trinity Opening on September 6th.

Syracosphaera pulchra Lohmann.—Occurred fairly frequently from September to the end of December, and then disappeared. It was recorded only twice near the island. The numbers never rose above 30 per litre.

Calyptrosphaera oblonga Lohmann.—Usually present in small numbers from July till the end of November, but became scarce in January, February and March, after which it reappeared. The highest number reached was 80 per litre at the weekly station on 30th July. Lohmann states that this species is restricted to salinities of $36°/_{\circ\circ}$ and above, and temperatures of 15° C. and above. In the Great Barrier Reef it would always find a suitable temperature, but seems to have adapted itself to lower salinity conditions.

Discosphaera tubifer Murray & Blackman.—Present in almost every sample at the weekly station from July till the end of November; then, except for a sample on 19th December, it disappeared completely. It was frequently present near the island also during the same period. The highest numbers recorded were 245 per litre in Trinity Opening on 24th August and 190 per litre at the weekly station on 11th September.

Rhabdosphaera stylifer Lohmann.—Frequent records at the weekly station and in Trinity Opening from the end of August to the end of October, after which it disappeared. The highest number recorded was only 20 per litre. It appeared only once near the island.

The Coccolithophores are known to us mainly from Lohmann's work in the Mediterranean and on the voyage of the "Deutschland" across the Atlantic. Most of them are restricted to oceanic conditions, and those appearing in the waters of the Great Barrier Reef lagoon are probably only survivors in the water brought in from outside the reef. A possible exception is *Calyptrosphaera*, which exists throughout the year in the lagoon. Lohmann considers that several of these species have their optimum at a depth of 50 m., but the figures are not large enough to confirm this.

SILICOFLAGELLATA.

Dictyocha Ehrenberg.—Rare, but more frequent in appearance than *Distephanus*.

Distephanus Stohr.—Rare, and appeared only occasionally throughout the year.

Euglenid flagellates.—From the end of November to the beginning of January these were frequently present in small numbers.

Minute unidentified flagellates were always present in numbers, varying up to about 500 per litre at the weekly station. They were always more abundant near the island, where the numbers on one occasion (13th August, 1928) rose to 4000 per litre.

RHIZOPODA.

Amoeba sp.—Rare. A small species was present in every sample but one at the weekly station on 20th September in numbers up to 170 per litre, but its appearances after this were infrequent.

Radiolarians.—Frequently present in small numbers throughout the year near the island. Scarce or absent at the weekly station till November, after which they were frequent. Most of them were Acantharians.

Foraminiferans.—Rare. Only occasional appearances.

CILIATA.

Leprotintinnus nordqvisti (Brandt).—A tropical neritic species present during most of the year and common in March.

Tintinnopsis Stein.—Present all the year round; common in the tow-nettings in March. The genus is widely distributed, most of the species being neritic or fresh-water.

Codonellopsis Jörgensen.—Usually present; common in the tow-nettings in January, February and March. The commonest species was *C. ostenfeldii*.

Coxliella laciniosa (Brandt).—Rare. Found only in Papuan Pass. A widely distributed warm-water species.

Epiplocylis Jörgensen.—Never common, but present in small numbers most of the year. It was more numerous at outside stations.

Protorhabdonella simplex (Cleve).—Scarce from November to May, but otherwise frequently present in small numbers.

Rhabdonella (Brandt).—Scarce from November to March, otherwise usually present.

Rhabdonellopsis Kofoid and Campbell.—Rare. Appeared a few times at the weekly station in August and September, and was found in Trinity Opening, Cook's Passage and Papuan Pass. A warm-water oceanic species.

Xystonella Brandt.—Very rare. Same distribution as *Rhabdonellopsis* but rarer.

Dictyocysta Haeckel.—Rare. Appeared in Papuan Pass and a few times in April and May at the weekly station.

Amphorella Daday.—Occurred throughout the year in small numbers. *A. quadrilineata* (Claparède and Lachmann) was the commonest species.

Amphorellopsis Kofoid and Campbell.—Appeared in February and occurred in small numbers afterwards; most numerous in May, June and July.

Dadayiella ganymedes (Entz Sr.).—Rare until November, and was almost always present in small numbers afterwards.

Tintinnus Schrank.—Present throughout the year, but always in small numbers.

Most of the genera, and even species, of Tintinnids occurring have a wide distribution throughout the oceans. Thus the species belonging to the genera *Leprotintinnus*, *Coxliella*, *Epiplocylis*, *Rhabdonella*, *Rhabdonellopsis*, *Xystonella*, *Dictyocysta*, *Amphorella* and *Tintinnus* have been recorded from the Atlantic, Pacific and Indian Oceans, and most of them from the Mediterranean.

Codonellopsis ostenfeldii has so far been recorded only from the Indian Ocean, the Red Sea, Arabian Sea, the Gulf of Siam and the Malay Archipelago, but closely allied species occur in the Pacific and Atlantic. *Amphorella quadrilineata* has perhaps the widest distribution, for it is recorded not only from the warm regions of the Atlantic, Indian and Pacific Oceans, but also as far as 42° S. in the Atlantic and as far north as the Irminger Sea, S.S.E. of Iceland.

Naked ciliates were present throughout the year, but as a rule only in small numbers. Occasionally a swarm of hypotrichous or peritrichous ciliates would appear in numbers up to 200 (weekly station, 14th June) or 750 (27th November, near the island) per litre.

CYANOPHYCEAE.

Trichodesmium Ehrenberg.—Occurrence very irregular, but it was most abundant in the calmer months from October to February.

T. erythraeum Ehrenberg and *T. thiebauti* Gomont occurred.

Richelia intercellularis Schmidt.—Common as a parasite in the cells of some of the larger *Rhizosolenia* spp. It is confined to warm seas and, according to Karsten, is more characteristic of neritic than of oceanic plankton.

TABLES III TO V.

In the following tables the number given is the number of cells, individuals, or (for *Trichodesmium*) threads, present in one litre of sea-water as calculated from the amount centrifuged.

Table III, Series I, from the weekly station.

Table IV, Series III, from outside stations.

Table V, Series II, from near the island.

TABLE III.

Station number.	Date (1928).	Number c.c. centrifuged.	Depth in metres.	Total diatoms.	Total dinoflagellates.	*Paralia.*	*Skeletonema.*	*Thalassiosira.*	*Hyalodiscus.*	*Coscinodiscus.*	*Planktoniella.*	*Asteromphalus.*	*Rhizosolenia.*	*R. stolterforthii.*	*Corethron.*	*Bacteriastrum.*	*Chaetoceros.*	*Hemiaulus.*	*Climacodium biconcavum.*	*C. frauenfeldianum.*	*Cerataulina.*	*Biddulphia.*	*Ditylum.*	Pennate diatoms.	*Nitzschia closterium.*	*Leptocylindrus*, large form.	*Leptocylindrus*, small form.	Unidentified diatoms.	*Pronoctiluca.*	*Amphidinium.*	*Gymnodinium* spp., colourless.	*G.* spp., green.	*Gyrodinium.*	*Cochlodinium.*	*Pouchetia.*	*Exuviella.*	*Prorocentrum.*	*Phalacroma.*	*Dinophysis.*	*D. caudata.*	*Ceratocorys.*	*Ornithocercus.*	*Amphisolenia.*	*Gonyaulax.*
H. 1	July 25	100	0	890	50	..	..	..	..	10	..	..	120	..	..	..	210	..	40	..	..	..	..	320	..	..	..	190	..	10	..	10	..	..	10	..	..	..	..	..	..	..	..	..
		,,	5	1250	40	..	..	..	..	..	..	10	100	..	..	..	180	..	..	..	..	..	..	770	..	..	..	190	..	..	..	..	..	10	..	..	..	..	..	20	..	..	..	..
		,,	10	540	30	..	..	..	..	20	..	..	70	..	..	..	80	..	..	..	..	..	..	320	..	..	..	50	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	12	520	30	..	..	..	..	10	..	..	30	..	..	..	20	..	..	..	..	..	..	460	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 2	July 27	100	0	740	80	..	..	..	..	..	..	..	80	..	..	..	60	..	..	..	..	..	..	460	60	..	..	80	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10
		,,	5	2280	60	..	..	..	..	..	..	..	50	..	..	..	50	..	..	..	..	..	..	1790	310	..	..	80	..	10	40	..	..	10	..	..	..	..	..	..	..	..	..	..
H. 3	July 30	100	0	1930	170	..	..	..	..	10	..	..	50	..	..	..	..	..	..	..	..	..	..	1410	440	..	..	20	..	20	80	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	1250	220	..	..	..	..	20	..	..	90	..	..	..	30	..	..	..	..	..	..	960	140	..	..	10	..	20	150	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	1330	110	100	..	..	..	40	..	..	60	10	..	..	10	..	..	..	..	..	..	960	150	..	..	..	..	10	30	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	930	80	40	..	..	..	..	..	..	80	..	..	..	..	..	..	..	..	..	..	710	100	..	..	..	..	..	20	20	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	1480	70	370	..	..	..	..	..	..	50	..	..	..	..	..	..	..	..	..	..	880	180	..	..	..	..	..	40	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	880	340	..	..	..	..	10	..	..	40	..	..	..	..	..	..	..	..	..	..	670	160	..	..	..	..	50	160	20	..	10	10	..	..	..	..	..	..	..	..	..
H. 4	Aug. 4	100	0	2160	380	440	..	..	..	..	..	..	160	30	..	..	190	..	..	..	..	..	..	1090	110	..	..	140	..	10	270	30	..	10	10	..	..	..	..	..	..	..	..	..
		,,	5	2210	220	310	..	..	..	20	..	..	110	40	..	..	180	10	..	..	..	..	..	1010	140	..	..	390	..	..	180	10	..	10	..	..	..	..	..	..	..	..	..	..
		,,	10	690	100	100	..	..	..	20	..	..	20	..	..	..	10	10	..	..	..	..	..	520	10	..	..	..	..	..	90	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	650	90	..	..	..	..	..	..	..	40	..	..	..	10	..	..	..	..	..	..	560	20	..	..	20	..	10	30	..	..	..	..	..	..	10	..	..	..	..	..	..
		,,	20	500	60	..	..	..	..	..	..	..	40	10	..	..	20	..	..	..	..	..	..	380	50	..	..	..	..	10	40	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	650	50	..	..	..	..	..	..	..	80	..	..	10	50	..	..	..	..	..	..	470	40	..	..	..	..	..	40	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	0	1980	120	100	..	..	..	..	..	..	190	200	..	10	190	20	..	..	..	..	..	970	160	..	..	140	..	10	50	..	..	..	..	..	..	10	..	..	..	..	..	10
H. 6	Aug. 11	100	0	1680	150	30	..	..	..	10	..	10	140	10	..	..	80	20	..	..	30	..	..	1150	140	..	..	60	..	10	470	20	..	..	..	..	..	10	..	..	..	..	..	..
		,,	5	1540	730	50	..	..	..	10	..	..	120	..	..	30	140	..	..	..	130	..	..	960	70	..	..	30	..	50	560	..	10	..	..	..	..	..	..	..	..	..	..	..
		,,	10	1620	290	120	..	..	20	10	..	..	100	..	..	..	40	70	..	..	40	..	..	1170	50	..	..	..	..	..	210	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	1690	250	100	..	..	..	10	..	..	170	30	..	..	170	40	..	..	..	..	..	1050	120	..	..	..	..	10	220	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	1380	310	40	..	..	..	10	..	..	40	70	..	..	..	..	..	..	30	..	..	1070	120	..	..	30	..	10	290	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	1760	360	..	..	..	..	10	..	..	200	30	..	..	150	60	..	..	..	..	..	1200	110	..	..	..	..	10	240	40	..	..	..	..	..	..	..	..	..	..	..	..
H. 7	Aug. 16	100	0	3650	980	40	..	..	..	..	..	..	520	90	..	..	90	20	90	..	..	..	..	2300	430	..	..	70	..	30	840	40	..	..	..	..	..	10	..	..	..	..	..	..
		,,	5	2600	450	..	..	..	..	..	..	..	450	40	..	70	100	50	..	..	230	..	..	1380	280	..	..	..	..	10	330	50	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	2170	420	..	..	..	..	..	..	..	500	30	..	..	..	..	30	..	50	..	..	1340	220	..	..	..	..	..	380	10	..	10	..	..	..	..	..	..	..	..	..	..
		,,	15	2890	200	80	..	..	..	20	..	..	560	210	..	70	260	170	60	..	30	..	..	1090	290	..	..	50	..	..	150	..	..	10	..	..	..	10	..	..	..	..	..	..
		,,	20	2950	440	370	..	..	..	..	..	..	580	70	..	30	300	100	70	..	70	..	..	1120	220	..	..	20	..	10	380	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	2570	250	40	..	..	..	20	..	..	460	80	..	20	220	..	20	..	150	..	..	1300	220	..	..	40	..	10	200	..	..	..	..	10	..	..	..	..	..	..	..	..
H. 11	Aug. 22	100	0	2850	450	..	..	..	10	..	..	..	620	60	..	50	580	..	80	..	..	..	..	1160	200	..	..	90	..	30	380	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	1920	180	240	..	..	..	..	..	..	320	10	..	..	200	10	30	..	10	10	..	900	160	..	..	30	..	10	150	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	1780	220	130	..	..	..	10	..	..	150	10	..	60	60	..	30	..	10	..	..	1070	210	..	..	40	..	..	180	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	1560	210	130	..	..	..	..	..	..	220	30	..	..	..	..	..	..	..	..	..	800	320	..	..	60	..	30	120	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	1520	80	360	..	..	..	..	..	..	200	..	..	..	..	..	20	..	..	..	..	740	170	..	..	30	..	10	30	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	1110	50	..	..	..	..	..	..	..	90	60	..	..	10	40	20	..	..	..	..	610	160	..	..	120	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 13	Aug. 31	20	0	29850	650	..	..	..	..	50	..	..	2450	150	..	1250	16000	50	..	..	150	..	..	4750	500	..	4500	..	..	..	600	..	..	..	..	..	..	..	..	..	..	..	..	..
		100	5	6780	270	270	..	..	..	10	..	..	1180	110	..	270	1110	110	40	..	..	..	..	2430	250	..	1000	..	..	10	160	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	6740	160	..	..	..	..	..	..	..	1160	260	..	160	950	190	..	..	..	..	..	2470	190	..	1360	..	..	..	110	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	8230	220	190	..	..	..	10	..	..	1300	310	..	250	1120	310	30	..	50	..	..	2680	220	..	1730	30	..	10	90	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	7060	270	470	..	..	..	10	..	10	1070	230	..	170	1300	110	..	..	110	10	..	2050	220	..	1250	50	..	..	130	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	10270	160	400	..	..	..	..	..	..	1430	340	..	600	2230	140	10	40	260	..	..	3050	240	..	1530	..	..	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 14	Sept. 4	100	0	880	460	..	..	..	..	..	..	..	160	40	..	50	150	30	20	..	..	..	..	300	40	..	80	10	..	..	370	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	1440	420	..	..	..	..	..	..	..	350	30	..	80	130	50	..	..	30	..	..	350	80	..	340	..	..	10	340	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	2080	450	..	..	..	..	..	..	..	380	70	..	50	240	..	..	..	20	..	..	640	50	..	630	..	..	20	380	..	..	..	..	..	..	20	..	..	..	..	..	..
		,,	15	2760	230	200	..	..	..	..	..	..	460	90	..	30	590	40	..	..	60	..	..	790	160	..	310	30	..	10	150	..	..	..	..	..	..	10	..	..	..	..	..	..
		,,	20	3200	220	100	..	..	..	..	..	..	770	70	..	40	310	40	..	..	90	..	..	1080	120	..	570	10	..	10	150	..	..	..	..	..	..	10	..	..	..	..	..	..
		,,	28	2760	220	100	..	..	..	..	..	..	720	40	..	100	480	60	..	..	..	..	..	880	140	..	240	..	..	10	150	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 16	Sept. 11	100	0	430	230	..	..	..	..	..	..	..	30	..	..	..	10	10	..	..	..	..	..	310	70	..	..	..	..	10	150	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	340	210	..	..	..	..	..	..	..	20	..	..	..	40	..	..	..	..	..	..	240	40	..	..	..	..	..	150	..	..	..	..	..	..	..	..	..	10	..	..	..
		,,	10	440	160	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	350	90	..	..	..	..	10	130	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	320	70	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	270	50	..	..	..	..	..	50	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	1140	110	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	980	160	..	..	..	..	10	70	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	1710	50	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	1460	230	..	..	..	..	10	20	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 17	Sept. 20	100	0	1630	230	180	..	..	..	..	..	..	30	..	..	..	130	..	..	..	..	..	..	980	310	..	..	..	..	10	180	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	1050	200	..	..	..	..	..	..	..	60	20	..	..	..	..	..	..	..	..	..	750	220	..	..	..	..	20	120	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	630	130	40	..	..	..	10	..	..	40	..	..	..	..	..	40	..	..	..	..	450	50	..	..	..	..	..	50	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	870	80	..	..	..	..	..	..	..	50	..	..	..	..	..	..	..	..	10	..	560	250	..	..	..	..	..	50	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	1120	140	100	..	..	..	10	..	..	50	..	..	..	10	..	..	..	..	..	..	780	170	..	..	..	..	10	60	20	..	..	10	..	..	20	..	..	..	..	..	..
		,,	28	1430	120	..	..	..	..	..	..	..	70	..	..	..	..	..	20	..	..	..	..	1060	280	..	..	..	..	10	50	20	..	..	..	..	..	..	..	..	..	..	..	..
H. 18	Sept. 26	100	0	310	170	40	..	..	..	..	..	..	..	..	..	..	50	..	..	..	..	..	..	140	80	..	..	..	..	..	120	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	260	230	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	160	40	..	50	..	..	..	170	10	..	..	..	..	..	..	..	..	..	..	..	..
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		,,	15	390	120	..	..	..	..	..	..	..	..	..	..	..	40	..	60	..	..	..	..	210	20	..	60	..	..	..	50	10	..	..	..	..	..	20	..	..	..	..	..	..
		,,	20	480	240	..	..	..	..	30	..	..	..	..	..	..	170	..	..	..	..	..	..	190	90	..	..	..	..	..	160	10	..	..	..	..	..	20	..	..	..	..	..	..
		,,	28	920	90	180	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	530	200	..	..	..	..	..	30	..	..	..	..	..	..	10	..	..	..	..	..	..
H. 19	Oct. 2	100	0	260	60	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	210	50	..	..	..	..	..	50	..	..	..	..	..	..	..	..	..	..	..	..	..
		200	5	360	85	45	..	..	..	..	..	..	5	..	..	..	10	..	20	..	..	..	..	270	10	..	..	..	..	..	50	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	425	75	75	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	280	65	..	..	..	..	10	35	15	..	..	..	..	..	5	..	..	..	..	..	..
		,,	15	425	30	40	..	..	..	..	..	..	15	..	..	..	..	5	20	..	..	..	..	285	50	..	10	..	..	..	15	..	..	..	5	..	..	..	..	..	..	..	..	..
		,,	20	300	35	25	..	..	..	..	..	..	..	..	..	..	..	..	15	..	..	..	..	215	45	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..
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H. 20	Oct. 8	200	0	130	90	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	105	15	..	..	..	..	..	40	5	..	..	..	5	5	..	..	..	..	..	..	..
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H. 21	Oct. 15	200	0	535	105	..	..	..	..	..	..	..	30	..	..	20	20	..	55	..	..	..	..	310	100	..	..	..	..	..	45	..	5	10	..	..	..	5	..	..	..	..	..	..
		,,	0	430	175	..	..	..	..	..	..	..	5	15	..	20	55	5	5	..	..	..	..	265	50	..	10	..	..	5	60	10	..	..	5	..	..	..	..	..	..	..	..	5
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		,,	10	585	70	..	..	..	..	..	..	..	65	5	..	35	40	..	10	..	..	..	..	310	120	..	..	..	..	..	25	..	..	5	5	..	..	..	..	..	..	..	..	..
		,,	15	650	65	105	..	..	..	..	..	..	10	..	..	..	15	..	65	..	..	..	..	310	125	..	20	..	..	5	15	5	..	..	..	..	..	5	..	..	..	..	..	..
		,,	20	575	25	45	..	..	..	..	..	..	30	35	..	5	..	..	75	..	..	..	..	295	90	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	1395	60	80	..	..	..	..	..	..	45	..	..	5	10	40	15	..	..	..	..	815	385	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 24	Oct. 23	200	0	35	110	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	30	5	..	..	..	..	..	65	20	..	..	..	..	..	5	..	..	..	..	..	..
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Diplopsalis type.	*Peridinium* spp.	Thecate, colourless peridinians.	Thecate, green peridinians.	*Pyrophacus*.	*Oxytoxum* spp.	*O. scolopax*.	*Ceratium candelabrum*.	*C. kofoidii*.	*C. furca* subsp. *eugrammum*.	*C. teres*, etc.	*C. fusus*.	*C. pennatum*.	*C. tripos*.	*C. macroceros*.	*C.* spp. unidentified.	*Podolampas*.	*Blepharocysta*.	Dinospores.	*Pontosphaera haeckeli*.	*Syracosphaera pulchra*.	*Calyptrosphaera oblonga*.	*Discosphaera tubifer*.	*Rhabdosphaera stylifer*.	*Distephanus*.	*Dictyocha*.	Euglenid flagellates.	Unidentified flagellates.	Amoeba.	Foraminifera.	Radiolaria.	*Tintinnopsis* spp.	*Codonellopsis*.	*Protorhabdonella*.	*Rhabdonella*.	*Dictyocysta*.	*Amphorella*.	*Amphorellopsis* and *Steenstrupiella*.	*Dadayiella*.	*Tintinnus*.	Unidentified Tintinnids.	Naked ciliates.	Unidentified cells.	Green algal cells.	Gelatinous colonies of algal cells.	*Trichodesmium*.	Copepod nauplii.	Copepods.	Ostracods.	Nematodes.	Polychaete larvae.	Other worms.	Echinoderm larvae.	*Cyphonautes* larvae.	Lamellibranch larvae.	Unidentified larvae.	Appendicularia.	Eggs.
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		25						5	5				5						5		5						35															35				10	5										
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							10	5			10								5								20															20				20	5										
	10	10	10					5														5					15													5		10			25	25											
		20				5		5					5								5						5								5					10			5	35	5										
		10											5														10																				40	20	15										
		20	5					10			5							5																						5			170	45											
	5	10	5																10			15					10														10			15												
	10		10												5			10			10					10													5				60	15									5		
		5								5								5			5					5														5			60	5											
5		10			5			5														25																				35		35	15	5										
		15	10										5						10			30														5				5		5			45	5	5										
	5	10	5		5			5					5						5			15					5														5	5			35	20											

TABLE III (*continued*).

Station number.	Date (1928–29).	No. c.c. centrifuged.	Depth in metres.	Total diatoms.	Total dinoflagellates.	*Paralia.*	*Skeletonema.*	*Thalassiosira.*	*Hyalodiscus.*	*Coscinodiscus.*	*Planktoniella.*	*Asteromphalus.*	*Rhizosolenia.*	*R. stolterforthii.*	*Corethron.*	*Bacteriastrum.*	*Chaetoceros.*	*Hemiaulus*	*Climacodium biconcavum.*	*C. frauenfeldianum.*	*Cerataulina.*	*Biddulphia.*	*Ditylium.*	Pennate diatoms.	*Nitzschia closterium.*	*Leptocylindrus*, large form.	*Leptocylindrus*, small form.	Unidentified diatoms.	*Pronoctiluca.*	*Amphidinium.*	*Gymnodinium* spp., colourless.	*G.* spp., green.	*Gyrodinium.*	*Cochlodinium.*	*Pouchetia.*	*Exuviella.*	*Prorocentrum.*	*Phalacroma.*	*Dinophysis.*	*D. caudata.*	*Ceratocorys.*	*Ornithocercus.*	*Amphisolenia.*	*Gonyaulax*
H. 25	Nov. 2	200	0	200	415	..	..	..	..	..	..	..	..	..	..	..	..	..	15	..	..	..	..	160	25	..	..	..	..	5	335	20	..	5	..	..	..	..	..	..	..	..	..	..
		,,	5	115	345	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	70	25	..	..	..	..	15	235	15	5	..	..	..	..	5	..	..	..	..	..	..
		,,	10	125	465	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..	..	95	15	..	..	..	..	20	275	30	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	165	345	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	135	30	..	..	..	..	10	210	50	..	..	..	5	..	..	..	..	..	..	..	5
		,,	20	150	145	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	135	5	..	..	..	..	5	65	35	..	..	..	..	..	..	5	..	..	..	..	..
		,,	28	715	145	125	..	..	..	..	..	..	50	..	..	..	..	..	..	..	..	..	..	395	145	..	..	..	..	5	80	45	..	..	..	..	..	5	..	..	..	..	..	..
H. 26	Nov. 6	200	0	155	965	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	130	15	..	..	..	..	..	590	260	..	..	5	..	..	..	..	..	..	..	..	5
		,,	5	125	535	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	100	5	..	..	..	..	..	370	105	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	70	260	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	70	..	..	..	..	..	5	175	35	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	120	130	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	80	40	..	..	..	..	..	55	55	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	370	130	60	..	..	..	5	..	..	5	..	..	15	..	..	..	..	..	..	..	230	55	..	..	..	..	..	70	35	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	395	140	5	..	..	..	..	..	..	5	..	..	..	10	..	..	..	..	..	..	360	15	..	..	..	..	..	60	50	..	..	..	..	..	..	..	..	..	..	..	..
H. 27	Nov. 16	100	0	4720	440	..	..	..	10	40	..	..	50	140	..	340	1310	60	40	..	270	..	10	1580	190	270	330	80	..	..	180	70	..	..	..	..	40	..	..	..	..	..	..	..
		,,	5	6080	310	280	..	..	10	20	..	..	150	130	..	230	1640	..	..	..	1150	..	..	1560	220	190	480	20	..	20	60	50	..	..	..	..	..	10	..	..	..	..	..	..
		,,	10	9310	150	..	80	..	..	10	..	10	130	60	..	1080	3550	140	80	90	630	..	..	2250	220	400	550	30	..	..	70	20	..	..	..	..	10	..	..	..	..	..	..	..
		,,	15	6320	140	50	40	..	..	20	..	..	120	120	..	1000	1240	..	..	..	600	20	..	1900	210	560	390	50	..	..	40	20	..	10	..	..	..	..	..	..	..	..	..	..
		,,	20	8510	70	..	..	..	..	40	..	..	160	240	..	1630	1920	60	30	..	820	..	..	1830	100	900	720	60	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	3670	20	..	..	..	..	10	..	..	170	40	..	390	730	40	..	..	480	..	..	1230	80	260	220	20	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..
H. 29	Nov. 21	200	0	215	345	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	160	50	..	..	..	..	5	250	45	..	5	..	..	..	..	..	..	..	..	..	..
		,,	5	265	285	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	220	45	..	..	..	..	..	190	60	5	..	..	..	..	..	..	..	..	..	..	..
		,,	10	420	220	50	..	..	..	..	..	..	5	..	..	..	10	..	..	..	..	..	..	330	25	..	..	..	..	5	130	50	..	..	5	..	..	..	..	..	..	..	..	..
		,,	15	575	160	30	..	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	410	110	..	..	..	..	5	115	25	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	860	255	50	..	..	..	5	..	..	15	..	..	..	5	..	..	..	..	..	..	635	150	..	..	..	..	5	190	10	..	..	5	..	..	..	..	..	..	..	..	..
		,,	28	795	130	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	5	..	660	115	..	..	..	..	..	105	15	..	..	..	..	..	..	..	..	..	..	..	..
H. 32	Nov. 28	200	0	230	660	..	..	..	..	..	..	..	..	..	..	..	..	..	25	..	..	..	..	160	40	..	..	5	..	5	390	145	..	..	25	..	..	..	..	..	..	..	..	..
		,,	5	180	270	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	125	25	25	..	..	..	..	200	15	5	..	10	..	..	..	..	..	..	..	..	..
		,,	10	120	140	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	105	5	..	..	..	..	..	100	10	..	..	10	..	..	..	..	..	..	..	..	..
		,,	15	185	160	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	155	25	..	..	..	..	..	115	25	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	250	150	..	..	..	..	..	..	..	..	..	..	..	..	..	40	..	..	..	..	185	25	..	..	..	..	5	55	50	..	..	..	..	..	10	..	..	..	..	..	..
		,,	28	825	35	20	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	630	165	..	..	..	..	5	10	..	..	..	5	..	..	5	..	..	..	..	..	..
H. 33	Dec. 5	200	0	685	355	..	..	..	..	..	..	..	15	5	..	5	45	..	65	..	80	..	..	375	25	50	20	..	..	..	150	30	..	..	..	..	..	5	..	..	..	..	..	..
		,,	5	1250	160	20	..	..	..	..	..	5	80	130	..	15	60	195	90	..	65	..	..	405	85	15	65	20	..	..	85	40	..	..	5	..	..	5	..	..	..	..	..	..
		,,	10	1160	135	60	..	..	..	5	..	..	30	60	..	15	215	..	90	..	95	..	..	490	60	5	35	..	..	5	65	20	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	3205	65	..	..	..	..	10	..	5	150	105	..	95	510	..	50	..	205	..	..	1785	215	35	40	..	..	..	40	5	..	5	5	..	..	..	..	..	..	..	..	..
		,,	20	2610	90	270	..	..	..	15	..	..	140	35	..	75	180	10	70	..	75	..	..	1575	130	25	10	..	..	..	45	10	..	5	5	..	..	..	..	..	..	..	..	..
		,,	28	2130	35	100	..	..	..	..	..	5	100	145	..	55	155	..	20	..	50	..	..	1315	140	45	..	..	..	..	10	..	..	..	5	..	..	..	..	..	..	..	..	..
H. 34	Dec. 13	200	0	615	250	..	..	..	..	15	..	..	30	..	..	55	50	..	45	..	..	..	..	365	30	15	10	..	..	..	115	25	..	10	..	..	..	..	..	..	..	..	..	..
		,,	5	515	185	..	..	..	..	5	..	..	15	10	..	..	70	..	20	..	40	..	..	305	20	30	..	..	..	..	95	40	..	..	15	..	..	..	..	..	..	..	..	5
		,,	10	690	235	..	..	..	..	15	..	..	35	30	..	20	105	..	10	..	5	..	..	390	25	55	..	..	..	20	145	5	..	..	15	..	..	..	..	..	..	..	..	10
		,,	15	715	60	35	..	..	..	20	..	..	45	15	..	20	95	..	15	..	10	..	..	390	50	20	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	760	60	35	..	..	..	5	..	..	45	25	..	35	200	25	15	..	..	..	..	320	55	..	..	..	..	..	35	5	5	..	..	..	..	..	..	..	..	..	..	..
		,,	28	765	120	35	..	..	..	10	..	..	50	30	..	85	65	..	15	..	15	..	..	395	50	15	..	..	..	..	80	25	..	..	..	..	..	..	..	..	..	..	..	..
H. 35	Dec. 19	200	0	285	1095	..	..	..	..	..	..	..	20	..	..	..	..	..	5	..	..	..	..	245	15	..	..	..	..	5	800	150	..	10	..	..	..	5	..	..	..	..	..	..
		,,	5	170	505	..	..	..	..	..	..	..	10	5	..	..	25	..	..	..	..	..	..	100	10	20	..	..	..	..	405	25	..	5	5	..	..	..	..	..	..	..	..	..
		,,	10	235	300	..	..	..	..	..	..	..	15	25	..	..	55	..	..	..	..	..	..	130	..	10	..	..	..	..	240	10	5	5	5	..	..	..	..	..	..	..	..	..
		,,	15	685	135	..	..	..	..	..	..	..	10	25	..	15	30	..	5	..	30	..	..	350	30	175	15	..	..	..	55	25	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	535	60	..	..	..	..	5	..	5	20	10	..	5	45	..	35	30	5	..	..	205	10	160	..	..	..	..	30	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	1130	50	35	..	..	..	20	..	..	105	40	..	15	140	..	5	..	20	..	..	690	30	25	..	5	..	..	25	10	..	..	5	..	..	..	..	..	..	..	..	..
H. 36	Dec. 27	200	0	420	355	..	..	..	..	..	..	..	35	25	..	30	105	..	..	..	..	..	..	130	20	20	55	..	..	5	240	35	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	95	225	..	..	..	..	..	..	..	30	..	..	..	25	..	..	..	..	..	..	35	5	..	..	..	..	..	120	30	..	..	5	..	..	..	..	..	..	..	..	..
		,,	10	220	345	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	60	..	85	20	35	..	..	240	15	..	5	..	..	..	..	..	..	..	..	..	..
		,,	20	1850	90	145	..	..	..	10	..	..	95	75	..	..	945	45	5	..	75	25	..	280	15	135	..	..	..	..	65	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	2960	40	..	..	..	..	15	..	..	225	205	..	90	1055	..	10	25	85	10	..	980	30	205	20	5	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 38	Jan. 14	200	0	220	120	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	185	20	..	10	..	..	5	75	..	..	..	..	..	5	..	..	..	..	..	..	..
		,,	5	150	100	..	..	..	..	5	..	..	5	..	..	..	..	..	..	..	..	..	..	125	15	..	..	..	..	..	75	..	..	..	5	..	..	..	..	..	..	..	..	..
		,,	10	245	55	..	..	..	..	5	..	..	5	..	..	..	35	..	..	..	..	..	..	170	15	15	..	..	..	..	40	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	300	115	..	..	..	..	..	..	5	15	..	..	15	15	..	..	..	..	..	..	220	30	..	..	..	..	5	75	15	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	405	45	35	..	..	..	15	..	..	10	..	..	..	15	..	..	..	5	..	..	300	30	..	..	..	..	..	35	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	405	5	..	..	..	..	5	..	..	5	..	..	..	75	..	..	..	..	..	..	295	20	..	..	5	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 39	Jan. 21	200	0	685	115	..	..	..	..	..	..	..	5	..	..	30	275	..	..	..	..	..	..	340	5	30	..	..	..	..	70	30	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	530	175	15	..	..	..	..	..	..	..	..	..	..	60	..	10	..	..	..	..	380	20	45	..	..	..	..	115	15	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	330	60	..	..	..	..	..	..	..	5	..	..	..	..	20	..	..	..	..	..	305	..	..	..	..	..	..	25	..	..	..	5	..	..	5	..	..	..	..	..	..
		,,	15	35	15	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	25	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	125	40	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	115	5	..	..	..	..	..	10	20	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	1030	40	..	..	..	..	..	..	..	30	..	..	..	..	..	15	..	5	..	..	945	35	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 40	Jan 30	200	0	1235	135	..	..	..	..	10	..	..	40	30	..	130	360	30	95	..	..	..	..	390	5	145	..	..	..	..	45	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	1980	95	..	..	..	..	15	..	..	40	110	..	75	580	25	105	..	75	..	..	580	10	365	..	..	..	..	25	20	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	1905	75	..	..	..	..	5	..	..	40	..	..	155	575	55	25	85	55	..	..	585	15	310	..	..	..	..	35	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	1555	50	35	..	..	..	5	..	5	65	10	..	320	475	40	..	40	5	..	..	390	5	160	..	..	..	..	20	5	..	..	..	..	..	..	..	..	..	..	5	..
		,,	20	2470	50	15	..	..	..	20	..	..	80	70	..	315	865	25	75	..	..	..	..	560	40	405	..	..	..	..	30	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	3950	15	..	..	..	10	25	..	..	190	65	..	310	1200	105	25	..	70	5	..	1315	20	600	..	10	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..
H. 41	Feb. 9	200	0	765	460	..	..	..	..	..	..	..	..	..	..	..	60	..	30	..	..	..	..	630	35	10	..	..	..	5	280	100	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	645	90	..	..	..	..	..	..	10	40	5	..	..	60	..	40	..	15	..	..	390	45	40	..	..	..	..	55	..	..	..	10	..	..	..	..	..	..	..	5	..
		,,	10	555	60	..	..	..	..	10	..	..	5	10	..	..	..	30	15	..	..	..	..	470	15	..	..	..	..	..	30	20	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	555	40	..	..	..	..	5	..	..	10	..	..	..	5	..	25	..	..	5	..	455	30	..	20	..	..	..	15	..	..	..	5	..	..	..	..	..	..	..	..	..
		,,	20	400	70	..	..	..	..	..	..	..	..	..	..	..	..	..	15	..	..	10	..	320	25	30	..	..	..	..	35	5	..	..	5	..	..	..	..	5	..	..	..	..
		,,	28	1520	75	275	..	..	..	75	..	..	25	..	..	..	65	..	5	..	..	..	..	965	55	20	..	35	..	..	55	5	..	..	..	..	..	..	..	..	..	..	..	..
H. 42	Feb. 13	200	0	335	495	..	..	..	..	..	..	..	5	..	..	..	65	20	10	..	..	..	..	135	25	55	20	..	..	..	420	15	..	5	..	..	..	..	..	..	..	..	..	..
		,,	5	465	115	..	..	..	..	..	..	..	20	..	..	..	..	..	90	..	..	..	..	325	30	..	..	..	..	..	85	10	10	..	..	..	..	..	..	..	..	..	..	..
		,,	10	485	65	..	..	..	..	..	..	..	..	..	..	..	30	..	45	35	..	..	..	335	15	25	..	..	..	..	40	..	..	..	10	..	..	..	..	..	..	..	..	..
		,,	15	510	85	..	..	..	..	10	..	..	70	..	..	35	10	..	80	..	..	..	..	300	5	..	..	..	..	..	65	5	..	..	..	..	..	5	..	..	..	..	..	..
		,,	20	2240	90	..	..	..	..	..	..	..	100	45	..	75	1115	60	85	..	80	..	..	500	20	80	80	..	..	..	75	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	4595	50	..	..	..	..	5	..	5	175	115	..	145	1270	60	125	5	320	..	..	1530	85	550	25	180	..	..	5	10	..	..	..	..	..	..	..	..	..	..	..	..
H. 43	Feb. 18	200	0	535	405	..	..	..	..	..	..	..	..	..	..	..	70	..	5	..	5	..	..	345	50	60	..	..	..	..	355	45	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	475	130	..	..	..	..	..	..	..	15	..	..	10	265	..	100	..	..	..	..	65	20	..	..	..	..	..	80	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	720	180	..	..	..	..	..	..	..	50	..	..	45	65	20	145	..	..	..	..	315	5	75	..	..	..	..	160	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	990	30	..	..	..	..	..	..	..	90	10	..	10	245	..	90	10	..	..	..	470	..	65	..	..	..	..	15	15	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	475	20	..	..	..	..	..	..	..	55	5	..	..	50	..	20	..	20	..	..	250	20	55	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	4075	45	..	..	..	..	..	..	..	220	25	..	110	1135	10	135	5	185	..	..	1885	100	265	..	..	..	..	35	5	..	..	..	..	..	..	..	..	..	..	..	..
H. 44	Mar. 4	200	0	760	130	..	..	..	..	10	..	5	15	5	..	..	60	..	..	10	..	..	..	495	105	55	..	..	..	..	70	20	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	950	145	..	..	..	..	5	..	..	70	..	..	20	100	..	15	..	..	..	..	470	50	220	..	..	..	..	80	35	5	..	..	..	..	..	..	..	..	..	..	..
		,,	10	1180	115	..	..	..	..	10	..	..	30	15	..	55	355	..	..	..	..	..	..	585	20	95	..	15	..	..	75	25	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	1650	105	..	..	..	..	5	..	5	100	20	..	65	555	30	5	35	5	5	..	570	75	[illegible]	..	..	..	..	85	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	1630	65	..	..	..	..	..	..	..	195	10	..	145	400	25	..	25	15	10	..	580	75	150	..	..	..	..	50	10	..	..	..	..	5	..	..	..	..	..	..	..
		,,	28	1665	5	..	..	..	..	5	..	..	155	25	..	65	520	..	60	..	20	10	..	535	135	95	..	40	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..

TABLE III (*continued*).

Diplopsalis type.	*Peridinium* spp.	Thecate, colourless peridinians.	Thecate, green peridinians.	*Pyrophacus.*	*Oxytoxum* spp.	*O. scolopax.*	*Ceratium candelabrum.*	*C. kofoidii.*	*C. furca* subsp. *eugrammum.*	*C. teres*, etc.	*C. fusus.*	*C. pennatum.*	*C. tripos.*	*C. macroceros.*	*C.* spp. unidentified.	*Podolampas.*	*Blepharocysta.*	Dinospores.	*Pontosphaera haeckeli.*	*Syracosphaera pulchra.*	*Calyptrosphaera oblonga.*	*Discosphaera tubifer.*	*Rhabdosphaera stylifer.*	*Distephanus.*	*Dictyocha.*	Euglenid flagellates.	Unidentified flagellates.	Amoeba.	Foraminifera.	Radiolaria.	*Tintinnopsis* spp.	*Codonellopsis.*	*Protorhabdonella.*	*Rhabdonella.*	*Dictyocysta.*	*Amphorella.*	*Amphorellopsis* and *Steenstrupiella.*	*Dadayiella.*	*Tintinnus.*	Unidentified Tintinnids.	Naked ciliates.	Unidentified cells.	Green algal cells.	Gelatinous colonies of algal cells.	*Trichodesmium.*	Copepod nauplii.	Copepods.	Ostracods.	Nematodes.	Polychaete larvae.	Other worms.	Echinoderm larvae.	*Cyphonautes* larvae.	Lamellibranch larvae.	Unidentified larvae.	Appendicularia.	Eggs.
..	..	20	25	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	10	..	..	..	..	..	..	..	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	115	..	..	..	..	..	..	..	..	..	..	..	..
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..	..	45	35	..	20	..	..	15	..	..	5	..	..	..	..	..	5	15	10	10	..	95	..	..	..	..	85	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..
..	5	25	15	..	15	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	5	70	..	..	..	..	65	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..
..	..	20	10	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	10	..	10	75	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
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..	..	30	15	..	..	..	..	10	..	..	..	..	..	..	..	..	15	5	..	..	..	..	..	..	..	..	255	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	180	..	..	..	..	..	..	..	..	..	..	..	..
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..	..	5	20	..	10	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	5	25	..	..	..	..	270	..	..	..	..	..	..	..	..	..	..	..	..	..	..	15	..	..	5	5	..	..	..	..	..	..	..	..	..	..	..
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..	5	10	10	..	..	..	..	..	..	..	..	..	..	..	..	..	5	5	..	..	..	..	..	..	..	5	10	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	5	15	5	..	..	..	..	..	..	..	..	..	..
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TABLE III—*(continued)*.

Station number.	Date (1929).	No. c.c. centrifuged.	Depth in metres.	Total diatoms.	Total dinoflagellates.	*Paralia.*	*Skeletonema.*	*Thalassiosira.*	*Hyalodiscus.*	*Coscinodiscus.*	*Planktoniella.*	*Asteromphalus.*	*Rhizosolenia.*	*R. stolterforthii.*	*Corethron.*	*Bacteriastrum.*	*Chaetoceros.*	*Hemiaulus.*	*Climacodium biconcavum.*	*C. frauenfeldianum.*	*Cerataulina.*	*Biddulphia.*	*Ditylium.*	Pennate diatoms.	*Nitzschia closterium.*	*Leptocylindrus*, large form.	*Leptocylindrus*, small form.	Unidentified diatoms.	*Pronoctiluca.*	*Amphidinium.*	*Gymnodinium* spp., colourless.	*G.* spp., green.	*Gyrodinium.*	*Cochlodinium.*	*Pouchetia.*	*Exuviella.*	*Prorocentrum.*	*Phalacroma.*	*Dinophysis.*	*D. caudata.*	*Ceratocorys.*	*Ornithocercus.*	*Amphisolenia.*	*Gonyaulax.*
H. 50	Mar. 15	200	0	3590	150	85	..	..	10	..	..	..	40	5	..	45	200	..	35	..	..	25	..	2100	885	160	..	..	..	5	100	5	..	..	..	..	..	5	..	..	..	..	..	..
		,,	5	2690	90	115	..	..	10	30	..	..	25	10	..	25	125	..	..	..	..	15	..	1490	725	120	..	..	..	..	75	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	3270	125	105	..	..	10	30	..	10	15	60	..	25	195	..	5	..	35	5	..	1740	965	70	..	..	..	5	110	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	3200	45	265	..	..	10	15	..	5	50	..	..	..	125	..	..	..	5	50	..	2030	635	10	..	..	..	..	25	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	2725	15	140	..	..	..	45	..	5	5	25	..	75	140	..	..	..	..	30	..	1780	435	45	..	..	..	..	10	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	3035	20	210	..	..	..	20	..	..	20	..	..	45	150	..	20	..	..	5	..	2065	495	5	..	..	..	..	15	..	..	..	..	..	..	..	..	5	..	..	..	..
H. 54	Mar. 25	150	0	5746	94	147	..	13	..	47	..	20	60	33	7	73	707	40	..	73	..	7	..	3253	533	340	313	80	..	..	47	13	..	..	..	..	..	..	..	..	..	..	..	..
		200	5	3715	10	130	..	10	..	25	..	5	105	20	..	50	605	5	15	..	..	30	..	2425	175	115	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..
		,,	10	5460	5	145	..	40	..	40	..	5	225	15	..	90	865	10	..	..	5	10	..	3455	320	235	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	5345	10	65	..	5	..	45	..	25	210	10	..	40	1010	110	..	..	5	25	..	3320	345	130	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	5805	10	70	..	35	..	35	..	15	325	15	..	45	920	145	15	15	20	30	..	3505	450	165	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	5540	0	65	..	10	..	65	..	20	275	50	..	35	795	20	10	..	5	..	..	3670	260	225	35	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 55	April 5	200	0	1255	75	..	..	..	..	5	..	5	15	5	..	50	140	45	80	..	..	..	..	770	110	30	..	..	5	..	45	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	1815	30	..	..	5	..	..	..	10	40	..	..	170	675	55	30	..	..	..	..	675	50	105	..	..	5	5	10	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	1720	65	..	..	5	..	..	..	5	30	..	..	270	380	70	15	..	..	..	..	895	25	25	..	..	..	..	45	..	..	..	..	..	..	..	..	..	..	..	5	..
		,,	15	2795	20	20	55	35	..	20	..	5	175	115	..	255	225	150	50	..	20	..	..	1435	150	80	..	5	..	..	15	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	3570	5	70	195	5	..	20	..	5	190	115	..	120	955	255	25	..	..	..	..	1350	190	20	..	55	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	9820	10	..	840	10	..	..	..	..	635	735	..	245	2265	325	65	..	95	..	..	3885	305	310	..	105	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 56	April 13	200	0	3855	85	150	..	..	..	5	..	..	70	15	5	80	995	30	20	..	..	..	..	1950	385	150	..	..	10	..	45	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	2765	35	..	..	15	..	..	..	..	50	10	..	10	745	60	135	..	..	..	..	1315	215	210	..	..	..	..	15	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	3025	55	90	..	..	..	10	..	..	110	55	..	115	420	75	75	10	..	..	..	1875	105	85	..	..	..	..	45	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	2325	20	..	..	5	..	5	..	15	125	25	..	35	270	60	60	..	10	..	..	1560	85	70	..	..	..	..	10	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	4050	25	..	..	..	..	5	..	..	80	10	..	105	740	75	35	25	..	..	..	2610	260	90	..	15	..	..	15	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	5480	10	90	..	5	..	..	..	..	130	60	..	165	995	145	45	..	..	..	..	3385	220	235	..	5	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..
H. 57	April 20	200	0	9080	85	130	..	30	..	..	..	..	285	155	..	370	1000	235	50	115	20	..	..	4860	1180	595	..	55	5	5	45	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	10470	85	110	35	80	..	40	..	5	250	190	..	230	925	85	60	55	15	25	..	6090	1825	435	..	15	..	..	50	10	..	..	..	..	5	..	..	..	..	..	..	..
		,,	10	8435	45	125	..	10	..	30	..	..	245	120	..	375	1100	80	80	15	40	..	..	4750	1160	290	..	15	..	..	20	5	..	..	..	..	5	..	..	..	..	..	5	..
		,,	15	6190	5	280	..	20	..	50	..	5	260	165	..	130	570	75	45	15	35	10	..	3735	580	210	..	5	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	4920	15	75	..	10	10	20	..	15	210	75	..	150	625	40	40	..	5	5	..	2730	835	65	..	10	..	..	5	..	..	..	..	..	..	..	..	..	..	..	5	..
		,,	28	6075	0	170	..	5	..	35	..	..	315	70	..	255	1135	105	60	5	..	5	..	3315	450	120	..	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 58	April 26	200	0	1075	265	..	..	..	..	..	..	..	15	25	..	30	80	..	55	..	..	..	..	800	15	55	..	..	15	..	135	30	..	10	10	..	..	..	..	..	..	..	5	..
		,,	5	870	90	..	..	..	..	5	..	10	65	15	..	20	80	10	10	..	..	..	..	590	45	..	..	20	..	..	55	..	..	..	..	5	..	..	..	..	..	..	5	..
		,,	10	2120	110	..	80	5	..	..	..	..	55	45	..	105	1025	30	..	..	..	..	..	745	30	..	..	..	..	..	70	..	..	..	..	..	..	5	..	..	..	..	..	..
		,,	15	2390	45	..	25	40	..	5	..	..	85	40	..	95	955	30	25	110	..	..	..	760	50	170	..	..	..	..	25	5	..	..	..	..	..	..	..	..	..	..	5	..
		,,	20	1045	10	45	..	..	..	5	..	10	100	..	..	20	5	10	..	10	..	..	..	700	90	45	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	28	2915	15	75	..	5	..	10	..	5	95	25	..	..	40	100	5	..	..	..	..	1830	690	30	..	5	..	..	10	5	..	..	..	..	..	..	..	..	..	..	..	..
H. 59	May 7	200	0	2120	235	10	..	..	..	..	..	..	25	..	..	..	80	..	..	..	..	..	..	1365	590	35	15	..	..	15	155	45	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	2580	205	100	30	..	..	5	..	5	50	..	..	5	30	..	..	..	5	..	..	1575	775	..	..	..	..	5	165	..	..	..	5	..	..	..	..	..	..	..	..	..
		,,	10	3040	200	40	..	..	..	10	..	10	45	30	..	10	40	..	..	..	..	..	..	1755	1100	..	..	..	..	..	170	15	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	4380	105	105	..	..	..	5	..	..	95	15	..	25	20	..	55	35	..	..	..	2500	1475	50	..	..	..	..	85	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	3105	110	105	..	..	..	5	..	5	40	..	..	10	20	20	20	5	..	..	..	1790	1080	..	..	5	..	..	105	..	..	..	..	..	..	..	..	..	..	..	5	..
		,,	28	2780	140	25	..	..	..	10	..	..	60	5	..	..	45	..	10	65	..	..	..	1835	725	..	..	..	..	..	105	10	..	..	..	..	..	..	..	..	..	..	5	..
H. 60	May 18	200	0	1715	185	20	..	5	..	10	..	5	40	55	..	120	150	25	..	..	..	..	..	1220	50	15	..	..	..	10	160	15	..	..	..	..	..	..	..	..	..	..	..	..
		..	5	1890	200	..	..	5	..	..	..	5	45	25	..	130	150	15	..	..	..	..	..	1435	45	15	..	20	..	..	175	5	..	..	..	..	..	..	..	..	..	..	..	..
		..	10	1675	105	..	..	5	..	..	..	5	10	5	..	15	205	10	..	..	..	..	..	1290	130	..	..	..	..	5	90	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	15	2750	55	75	..	..	..	30	..	10	50	45	..	125	235	..	..	..	..	..	..	1800	380	..	..	..	..	5	45	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	20	2480	105	40	..	..	..	30	..	..	25	5	..	..	120	..	..	..	..	..	..	1915	345	..	..	..	..	..	100	5	..	..	..	..	..	..	..	..	..	..	..	..
		..	28	3325	40	115	..	..	..	15	..	5	115	10	..	215	30	20	..	10	..	..	..	2235	545	10	..	..	..	..	30	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 61	May 25	200	0	3115	270	15	..	..	..	5	..	..	30	25	..	35	230	5	140	..	..	..	..	2080	505	40	..	5	..	..	200	15	5	..	..	5	..	..	..	..	..	..	5	..
		..	5	2725	230	115	..	..	..	..	..	5	35	15	..	65	340	20	30	..	..	..	..	1515	435	150	..	..	..	5	165	15	..	..	..	..	..	..	..	..	..	..	..	..
		..	10	2385	110	100	..	..	..	10	..	..	40	10	..	25	195	10	..	..	..	..	..	1620	340	35	..	..	..	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	15	3305	130	125	..	..	..	5	..	5	45	25	..	50	350	..	50	..	..	..	..	2205	380	65	..	..	..	..	60	10	5	..	..	..	5	..	..	..	..	..	5	..
		..	20	3055	100	105	..	..	..	35	..	5	75	25	..	65	195	..	20	..	..	..	..	2170	360	..	..	..	..	..	60	5	5	..	10	..	..	..	..	..	..	..	..	..
		..	28	6000	80	15	..	..	..	65	..	5	65	30	..	75	350	55	70	..	30	5	..	4460	700	55	10	10	5	..	50	10	..	5	..	..	..	..	..	..	..	..	..	..
H. 62	May 31	200	0	3245	235	85	..	..	..	5	..	5	60	5	..	70	385	75	..	..	..	..	..	1900	585	70	..	..	10	5	85	45	..	..	..	5	5	..	..	..	..	..	..	5
		,,	5	1490	175	..	..	..	..	..	..	10	5	..	..	100	65	..	10	..	..	..	..	925	320	55	..	..	5	..	100	..	..	5	..	..	..	..	..	..	..	..	..	5
		..	10	2090	100	..	..	..	..	10	..	..	40	15	..	95	640	50	75	75	..	..	..	860	220	10	..	..	10	..	35	5	..	5	..	..	..	..	..	..	..	..	..	..
		,,	15	3075	85	175	..	..	..	..	..	..	15	25	..	80	240	25	20	..	..	20	..	2045	380	50	..	..	..	..	40	..	..	..	..	..	5	..	..	..	..	..	..	..
		..	20	2285	50	10	..	..	..	..	..	5	10	..	..	20	190	55	25	..	..	..	..	1640	320	10	..	..	..	..	40	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	28	4465	55	60	..	..	..	30	..	..	65	10	..	125	390	5	..	..	..	..	..	3165	510	105	..	..	..	..	15	5	..	..	..	..	..	..	..	..	..	..	..	..
H. 63	June 7	200	0	725	90	..	..	..	5	..	..	..	15	..	..	5	105	..	15	..	..	..	..	345	30	205	..	..	15	..	50	5	10	..	..	..	..	..	..	..	..	..	..	..
		..	5	1190	175	..	..	..	..	..	..	..	10	..	..	95	460	..	..	..	..	..	..	435	160	30	..	..	..	..	90	20	5	5	5	..	5	..	..	..	..	..	..	..
		..	10	845	55	65	..	..	..	..	..	5	20	..	..	..	195	..	..	..	..	..	..	395	120	45	..	..	..	..	25	..	..	..	..	10	..	..	..	..	..	..	..	..
		..	15	1140	105	80	..	..	..	..	..	..	35	5	..	..	145	5	10	..	50	..	..	600	165	45	..	..	..	5	75	15	..	..	..	5	..	..	..	..	..	..	..	..
		..	20	7150	45	200	..	..	..	..	..	5	45	..	..	20	335	40	45	..	5	..	..	5895	440	120	..	..	..	..	30	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	28	7580	30	..	..	..	..	15	..	..	25	..	..	20	230	70	15	..	..	..	..	6220	885	95	..	5	..	..	30	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 64	June 14	200	0	4980	450	..	25	5	..	5	..	5	65	115	..	330	855	55	..	..	..	..	..	2315	975	225	..	5	..	30	230	60	..	5	5	..	5	10	..	..	..	..	5	..
		..	5	3825	145	190	..	..	..	15	..	5	75	70	..	95	630	5	..	..	..	..	..	1765	685	290	..	..	..	..	55	15	..	15	..	..	..	..	..	..	..	..	5	..
		..	10	4075	95	190	..	..	..	5	..	..	110	50	..	110	305	35	..	..	..	15	..	1630	1465	155	..	5	..	..	45	10	5	..	..	..	..	..	..	..	..	..	..	..
		..	15	2920	135	100	..	..	..	5	..	..	65	100	..	100	515	65	35	..	..	..	..	1160	715	60	..	..	..	..	85	5	..	5	..	..	..	..	..	..	..	..	..	..
		..	20	2620	100	70	..	..	..	10	..	5	70	35	..	85	410	..	..	..	..	..	..	1085	660	190	..	..	..	..	65	5	..	5	..	..	..	..	..	..	..	..	..	..
		..	28	2680	50	125	..	..	..	20	..	..	80	85	..	10	355	..	..	..	..	..	..	1315	565	125	..	..	..	..	40	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 65	June 24	200	0	3280	220	..	..	..	..	20	..	10	145	40	..	500	1350	10	5	..	..	..	..	760	245	195	..	..	..	..	90	25	..	5	5	..	..	5	..	..	..	..	..	..
		..	*5	2190	80	..	..	..	..	..	..	..	190	170	..	220	910	30	30	..	10	..	..	460	130	40	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	*10	1665	40	..	..	..	..	15	..	..	115	170	..	100	665	..	..	35	10	..	..	350	65	140	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	*15	1500	50	..	..	..	..	5	..	..	95	135	..	215	655	20	5	..	10	..	..	255	55	50	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	*20	1110	30	35	..	..	..	..	..	5	205	55	..	80	340	..	10	..	10	..	..	230	65	75	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	*28	1235	5	25	..	..	..	5	..	..	60	15	..	125	540	..	10	..	10	..	..	355	60	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 66	July 5	200	0	2130	145	215	..	..	..	..	..	5	85	15	..	75	70	10	..	..	20	5	..	1265	250	110	..	5	5	..	105	10	..	..	..	..	..	..	..	..	..	..	..	..
		..	5	1955	85	50	..	..	..	5	..	..	35	10	..	5	85	..	..	..	..	..	..	1460	275	30	..	..	..	..	50	15	..	..	..	..	..	..	..	..	..	..	..	..
		..	10	2735	90	200	..	..	..	5	..	..	50	30	..	25	95	..	10	..	10	..	..	1620	640	50	..	..	..	..	60	5	..	..	..	..	..	..	..	..	..	..	..	..
		..	15	2655	30	25	..	..	5	5	..	..	50	5	..	..	100	..	10	..	5	..	..	1810	640	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	20	2495	110	125	..	..	..	..	..	..	45	5	..	..	30	..	20	..	..	..	..	1565	595	80	..	30	5	..	75	10	..	..	..	..	5	..	..	..	..	..	..	..
		..	28	3350	25	70	..	..	..	5	..	..	40	20	..	..	130	..	10	..	..	..	..	2280	775	20	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 67	July 11	200	0	1200	360	..	..	..	..	..	..	..	210	25	..	120	150	5	..	..	5	..	..	495	95	95	..	..	..	..	250	20	..	..	..	..	..	..	..	..	..	..	..	..
		..	5	1525	235	..	..	..	..	5	..	..	190	50	..	185	335	20	10	..	10	..	..	565	85	45	..	25	..	..	140	5	5	10	..	..	..	..	..	..	..	..	..	..
		..	10	1690	300	20	..	..	..	10	..	5	235	35	..	65	300	5	40	..	25	..	..	765	125	60	..	..	..	5	190	15	..	..	..	..	..	5	..	5	..	..	..	..
		..	15	1930	235	..	..	..	10	10	..	..	260	60	..	95	145	5	5	..	..	..	..	590	185	265	..	..	5	..	115	10	5	..	..	..	..	..	..	..	..	..	..	..
		..	20	1375	140	35	..	..	..	..	..	..	165	45	..	65	260	..	15	..	..	..	..	615	110	65	..	..	5	..	65	10	..	..	5	..	..	..	..	..	..	..	..	..
		..	28	2415	40	580	..	..	..	..	..	..	205	40	..	70	175	25	15	..	35	..	..	1000	235	35	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 68	July 17	200	0	2800	370	..	..	..	..	..	..	5	165	25	..	110	185	60	..	30	30	..	..	1610	325	255	..	..	5	..	240	20	5	..	..	5	..	5	..	..	..	..	..	..
		..	5	4090	355	150	..	..	..	..	..	5	190	70	..	165	430	45	..	..	..	..	..	2310	290	435	..	..	..	..	210	5	..	..	..	..	..	..	..	..	..	..	..	..
		..	10	2800	175	230	..	..	..	5	..	10	125	25	..	155	455	60	5	..	40	..	..	1085	150	455	..	..	5	..	65	15	..	5	..	..	10	..	..	..	..	..	..	..
		..	15	3090	190	115	..	..	..	10	..	..	105	60	..	25	525	40	..	..	15	..	..	1665	245	285	..	..	..	..	100	10	..	..	..	..	5	..	..	..	..	..	5	..
		..	20	1815	105	..	..	..	..	..	..	..	85	10	..	40	195	5	15	..	5	..	..	1000	145	315	..	..	..	..	80	..	..	..	..	..	..	..	..	..	..	..	..	..
		..	28	1900	85	100	..	..	5	..	..	5	145	55	..	80	205	60	5	..	20	..	..	885	130	205	..	..	5	..	65	..	..	..	..	5	..	..	..	..	..	..	..	..

* Sample preserved in Flemming.

Diplopsalis type	*Peridinium* spp.	Thecate, colourless peridinians.	Thecate, green peridinians.	*Pyrophacus.*	*Oxytoxum* spp.	*O. scolopax.*	*Ceratium candelabrum.*	*C. kofoidii*	*C. furca* subsp. *eugrammum.*	*C. teres*, etc.	*C. fusus.*	*C. pennatum.*	*C. tripos.*	*C. macroceros.*	*C.* spp. unidentified.	*Podolampas.*	*Blepharocysta.*	Dinospores.	*Pontosphaera haeckeli.*	*Syracosphaera pulchra.*	*Calyptrosphaera oblonga.*	*Discosphaera tubifer.*	*Rhabdosphaera stylifer.*	*Distephanus.*	*Dictyocha.*	Euglenid flagellates.	Unidentified flagellates.	Amoeba.	Foraminifera.	Radiolaria.	*Tintinnopsis* spp.	*Codonellopsis.*	*Protorhabdonella.*	*Rhabdonella.*	*Dictyocysta.*	*Amphorella.*	*Amphorellopsis* and *Steenstrupiella.*	*Daduyiella.*	*Tintinnus.*	Unidentified Tintinnids.	Naked ciliates.	Unidentified cells.	Green algal cells.	Gelatinous colonies of algal cells.	*Trichodesmium.*	Copepod nauplii.	Copepods.	Ostracods.	Nematodes.	Polychaete larvae.	Other worms.	Echinoderm larvae.	*Cyphonautes* larvae.	Lamellibranch larvae.	Unidentified larvae.	Appendicularia.	Eggs.
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..	..	5	..	..	..	5	..	5	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	10	..	5	..	..	..	..	5	5	..	..	..	..	..	..	..	..	..	..	..
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5	45	15	..	..	..	..	..	15	..	..	..	..	5	..	..	..	5	..	..	..	..	..	..	..	..	..	25	..	..	..	..	..	5	..	..	..	..	..	..	5	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5	20	15	..	..	..	..	..	25	..	..	5	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..
..	5	..	5	..	..	..	..	60	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	65	..	..	5	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..
5	5	..	5	..	..	..	..	60	..	..	15	..	..	..	..	5	5	..	..	..	..	..	..	..	10	..	60	..	..	..	..	..	20	..	..	..	..	..	..	..	20	5	..	5	15	5	..	..	..	..	..	..	..	..	..	..	..
5	5	..	..	..	..	..	..	35	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	30	..	..	5	..	..	15	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	5	..	..	..	..	..	5	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	5	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	25	..	..	5	5	..	35	..	..	10	..	..	..	..	5	5	..	..	..	..	..	..	..	..	..	30	..	..	5	..	..	20	5	..	..	..	..	..	..	5	15	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..
10	10	40	5	..	..	..	..	50	..	10	..	..	5	..	..	..	10	..	..	..	..	..	..	..	..	..	65	..	..	5	..	..	20	..	..	5	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	5	..	..	..	..	..	..	55	..	..	10	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	25	..	..	..	..	..	35	..	..	..	..	..	..	..	..	15	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..
5	5	5	..	..	..	..	..	30	5	..	10	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	5	..	5	..	..	5	..	10	5	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..
..	5	..	..	..	..	..	..	15	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	30	..	..	..	..	..	5	..	..	..	..	5	..	5	..	5	..	..	60	..	..	..	..	..	..	..	..	..	..	..	..
..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	5	5	..	..	..	..	..	..	..	..	..	..	..	..

TABLE IV.

Station number.	Date (1928–29).	Number c.c. centrifuged.	Depth in metres.	Total diatoms.	Total dinoflagellates.	*Paralia.*	*Skeletonema.*	*Thalassiosira.*	*Hyalodiscus.*	*Coscinodiscus.*	*Planktoniella.*	*Asteromphalus.*	*Rhizosolenia.*	*R. stolterforthii.*	*Corethron.*	*Bacteriastrum.*	*Chaetoceros.*	*Hemiaulus.*	*Climacodium biconcavum.*	*C. frauenfeldianum.*	*Cerataulina.*	*Biddulphia.*	*Ditylium.*	Pennate diatoms.	*Nitzschia closterium.*	*Leptocylindrus*, large form.	*Leptocylindrus*, small form.	Unidentified diatoms.	*Pronoctiluca.*	*Amphidinium.*	*Gymnodinium* spp., colourless.	*G.* spp., green.	*Gyrodinium.*	*Cochlodinium.*	*Pouchetia.*	*Exuviella.*	*Prorocentrum.*	*Phalacroma.*	*Dinophysis.*	*D. caudata.*	*Ceratocorys.*	*Ornithocercus.*	*Amphisolenia.*	*Gonyaulax.*
H. 12	Aug. 24	100	0	190	400	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	120	70	..	..	..	..	10	270	20	..	..	..	30	..	..	..	..	..	..	..	..
		200	5	125	130	..	..	..	..	5	..	..	65	..	..	..	15	..	..	..	..	..	..	35	5	..	..	..	..	..	110	..	..	..	..	..	..	5	..	..	..	..	..	..
		,,	10	530	70	..	..	..	..	5	..	..	410	5	..	..	80	..	..	..	..	..	..	25	5	..	..	..	..	..	50	10	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	90	130	..	..	..	..	5	..	..	15	..	..	..	15	..	..	..	..	..	..	45	10	..	..	..	..	5	80	..	..	..	..	5	..	..	..	..	..	..	..	..
		,,	30	135	125	..	..	..	..	..	..	..	50	..	..	..	5	..	..	..	..	..	..	60	20	..	..	..	..	..	75	..	..	..	..	10	..	..	..	..	..	..	..	..
		,,	40	850	65	..	..	..	..	5	..	..	225	65	..	15	75	30	40	..	..	..	..	265	15	..	..	115	..	..	35	10	..	..	..	..	..	..	..	..	..	..	..	..
H 15	Sept. 6	200	0	750	460	..	..	..	..	..	..	..	110	..	..	10	430	..	..	..	..	..	..	120	45	..	35	..	..	..	420	20	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	505	255	..	..	..	..	..	..	..	50	5	..	..	330	..	..	..	..	..	..	95	15	..	..	10	..	..	200	5	..	..	..	5	..	..	..	..	..	..	..	..
		,,	10	1200	310	..	..	..	..	..	..	..	40	..	..	..	935	..	..	..	..	..	..	140	55	..	25	5	..	..	280	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	705	150	..	..	..	..	..	..	..	30	..	..	..	490	..	..	..	..	..	..	150	35	..	..	..	..	..	125	..	..	..	..	..	..	5	..	..	..	..	..	..
		,,	30	260	165	..	..	..	..	..	..	..	40	..	..	..	100	..	..	..	..	..	..	85	25	..	10	..	..	5	150	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	40	135	135	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	100	15	..	..	..	..	..	85	25	..	..	..	..	..	..	..	..	..	..	..	..
		,,	55	490	175	..	..	..	..	..	..	..	95	..	..	..	30	..	..	..	..	..	..	340	20	..	..	5	..	..	150	20	..	..	..	..	..	..	..	..	..	..	..	..
H. 22B	Oct. 20	200	0	195	140	..	..	..	..	..	..	..	20	15	..	..	60	..	25	..	..	..	..	70	5	..	..	..	..	..	80	15	..	..	..	..	..	5	..	..	..	..	..	..
		,,	5	95	155	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	50	10	..	10	5	..	10	60	35	..	..	..	..	..	10	10	..	..	..	5	..
		,,	10	80	20	..	..	..	..	..	..	..	5	10	..	..	..	..	25	..	..	..	..	40	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*20	35	45	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	10	15	..	..	..	..	..	5	..	..	..	..	..	..
		,,	50	220	..	..	..	..	..	..	..	..	40	..	5	..	55	..	..	..	..	..	..	115	5	..	..	..	..	5	..	10	..	..	5	..	..	..	..	..	..	..	..	..
		,,	100	15	25	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	10	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*180	25	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 23	Oct. 20	200	0	20	85	..	..	..	..	..	..	..	..	..	..	..	..	..	15	..	..	..	..	5	..	..	..	..	..	..	30	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*100	130	50	..	..	..	..	..	5	..	5	..	..	..	80	..	..	..	..	..	..	40	..	..	..	..	..	..	30	..	..	..	..	..	..	5	..	..	..	..	..	..
		,,	300	5	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	500	20	5	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 28	Nov. 19	200	0	470	565	..	..	..	..	10	..	..	5	..	..	..	5	..	..	..	..	..	..	265	165	..	20	..	..	5	320	150	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	475	765	..	..	..	..	..	..	..	15	..	..	10	..	..	..	..	5	..	..	360	80	..	..	5	..	10	565	35	5	..	..	..	..	..	..	..	..	..	..	..
		,,	10	335	280	..	..	..	..	..	..	..	15	..	..	..	10	..	..	..	..	..	..	180	120	..	..	10	..	5	215	35	..	..	..	..	..	..	..	..	..	..	..	..
		,,	15	270	335	..	..	..	..	5	..	..	10	..	..	..	..	..	..	..	..	..	..	180	60	..	..	15	..	30	200	60	..	..	5	..	..	15	..	..	..	..	..	..
		,,	30	695	370	50	..	..	..	20	..	5	5	..	..	..	..	..	..	..	..	..	..	450	140	..	..	25	..	5	260	50	..	..	5	..	45	..	..	..	..	..	..	..
		,,	50	985	175	..	..	..	..	25	..	5	30	..	..	25	55	..	..	..	15	5	..	585	195	..	15	30	..	..	90	10	..	..	10	..	5	5	..	..	..	..	..	..
H. 30	Nov. 23	200	0	150	250	..	..	..	..	10	..	..	10	..	..	..	..	..	30	..	..	..	..	65	35	..	..	..	..	..	235	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	100	260	..	..	..	..	5	..	..	15	..	..	..	5	..	25	..	..	..	..	35	15	..	..	..	..	5	230	..	..	..	..	..	..	..	..	..	..	5	..	..
		,,	25	145	85	..	..	..	..	5	..	..	5	..	..	..	..	70	5	..	..	..	..	45	15	..	..	..	..	5	25	20	..	5	..	..	..	5	..	..	..	..	..	..
		,,	50	110	100	..	..	..	..	..	..	..	..	..	..	..	5	60	..	..	..	..	..	45	..	..	..	..	..	15	45	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	100	140	35	..	..	..	..	5	5	..	..	..	..	..	..	..	..	..	..	..	..	25	5	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	200	50	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	40	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	400	25	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	600	20	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 31	Nov. 24	200	0	210	200	..	..	..	..	5	..	..	20	..	..	..	65	..	..	..	..	..	..	90	30	..	..	..	..	10	155	5	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	215	175	..	..	..	..	..	..	..	..	..	..	25	30	25	..	..	..	..	..	120	15	..	..	..	..	5	125	25	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	180	110	..	..	..	..	5	..	..	25	..	..	..	..	..	10	..	..	..	..	125	15	..	..	..	..	5	85	15	..	..	..	..	..	..	..	..	..	..	..	..
		,,	20	160	120	..	..	..	..	..	..	..	5	..	..	..	55	20	..	..	..	..	..	75	5	..	..	..	..	..	80	30	..	5	..	..	..	..	..	..	..	..	..	..
		,,	28	535	45	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	510	25	..	..	..	..	..	20	10	..	..	..	..	..	5	..	..	..	..	..	..
H. 45	Feb. 26	200	0	9745	120	..	..	..	..	..	..	..	295	60	..	80	7150	25	75	..	90	..	..	710	230	1030	..	..	..	..	90	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*5	4520	0	..	..	..	..	5	..	..	105	75	..	280	3480	15	20	..	30	..	..	230	35	245	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*10	2110	20	..	..	..	..	20	..	..	205	90	..	25	1230	..	..	..	10	..	..	325	65	140	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*20	2120	10	..	..	..	..	5	..	..	285	50	..	55	655	..	30	..	15	..	..	725	155	120	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 46	Feb. 27	100	0	3460	90	..	..	..	..	..	..	..	300	170	..	310	1370	150	..	20	50	..	..	780	140	170	..	..	..	..	50	10	..	..	..	..	..	..	..	..	..	..	..	..
		200	*5	1355	0	..	..	..	..	..	..	..	140	15	..	115	665	5	..	..	15	..	..	255	20	110	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*10	1995	15	..	..	..	..	..	..	..	115	75	..	255	930	20	..	..	30	..	..	305	60	160	..	45	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*20	6330	40	..	..	..	..	..	..	..	390	180	..	195	4075	..	..	..	40	..	..	930	110	400	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*28	5310	0	..	130	..	..	25	..	..	640	565	..	5	1210	65	10	10	75	..	..	2230	115	190	..	40	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H 47	Feb. 28	200	0	5860	25	..	..	..	..	5	..	..	225	115	..	230	4145	20	35	20	30	..	..	490	35	495	..	15	..	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*10	3920	30	..	..	..	..	..	..	..	265	85	..	355	1865	10	35	..	90	5	..	715	80	415	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..
		,,	*25	3190	25	..	..	..	..	..	..	..	235	90	..	165	1510	80	20	20	80	..	..	450	75	450	..	15	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..
		,,	*50	3045	35	..	..	..	..	..	..	..	185	30	..	75	2225	15	10	..	45	..	..	210	5	235	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*100	1005	10	10	..	..	..	15	..	5	115	15	..	35	425	10	..	10	..	..	..	280	25	60	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*200	110	0	..	..	..	..	..	..	..	5	..	..	..	25	..	..	..	10	5	..	60	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*400	25	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 48	Feb. 28	200	*5	6840	55	..	..	..	..	..	..	..	125	155	..	150	5175	55	..	55	20	..	..	830	30	225	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*15	5740	30	..	..	10	..	..	..	..	130	135	..	60	4600	45	..	40	5	..	..	505	25	105	..	80	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*20	1945	45	..	..	..	..	..	..	5	265	75	..	..	645	..	..	225	5	..	..	515	25	160	..	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*28	3700	15	..	90	..	..	..	..	..	335	85	..	15	2065	90	..	45	35	..	..	655	120	135	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 51	Mar. 17	140	*0	1090	20	..	150	..	..	..	..	..	65	25	..	125	235	..	..	..	..	..	..	365	40	85	..	..	..	..	..	5	..	..	..	..	5	..	..	..	..	..	..	..
		200	*5	890	0	..	..	..	..	20	..	..	35	40	..	60	270	10	..	..	..	..	..	375	15	65	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*10	775	45	..	..	10	..	5	..	..	35	50	..	25	225	10	5	..	..	..	..	345	35	30	..	..	..	..	5	..	..	..	..	..	10	..	..	..	..	..	..	..
		,,	*20	650	15	..	..	10	..	..	..	5	35	15	..	10	120	..	..	..	..	..	..	410	15	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*30	515	10	..	..	..	..	5	..	..	55	15	..	..	55	..	..	..	..	..	..	305	15	65	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*40	200	5	..	..	..	..	5	..	..	40	..	..	5	20	..	..	..	..	..	..	130	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 52	Mar. 18	200	0	1160	245	..	..	..	..	10	..	..	45	20	..	190	125	5	5	..	..	..	..	400	175	170	..	15	..	..	150	50	..	..	..	..	..	..	..	..	..	..	..	..
		,,	5	1495	285	..	..	..	..	10	..	..	70	65	..	165	355	..	80	..	..	..	..	475	105	170	..	..	..	..	195	75	..	..	..	..	..	..	..	..	..	..	..	..
		,,	10	810	170	30	..	..	..	5	..	..	35	5	..	30	200	25	10	..	..	..	..	185	10	275	..	..	..	..	140	10	..	..	10	..	..	..	..	..	..	..	..	..
		,,	*20	1590	10	..	..	15	..	..	..	..	80	35	..	220	850	40	..	..	..	..	..	255	5	75	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*50	855	5	..	..	..	..	..	..	..	95	10	..	110	230	30	..	..	20	..	..	235	5	120	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*100	400	0	15	..	..	..	..	..	..	20	..	..	70	140	..	..	..	..	..	..	120	15	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*200	20	0	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		,,	*500	45	10	..	..	..	..	..	..	..	..	..	..	30	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 53	Mar. 18	200	*100	45	5	..	..	5	..	..	..	..	5	..	..	..	..	..	..	..	..	5	..	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 47A	Mar. 8	200	*0	6295	160	..	..	30	..	5	..	..	1040	245	..	30	1830	100	..	25	10	..	..	2540	40	290	..	110	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H. 58A	April 27	200	*0	365	20	..	..	..	..	..	..	..	150	..	..	30	20	10	5	..	5	..	..	130	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

* Sample preserved in Flemming.

Diplopsalis type.	*Peridinium* spp.	Thecate, colourless peridinians.	Thecate, green peridinians.	*Pyrophacus.*	*Oxytoxum* spp.	*O. scolopax.*	*Ceratium candelabrum.*	*C. kofoidii.*	*C. furca* subsp. *eugrammum.*	*C. teres*, etc.	*C. fusus.*	*C. pennatum.*	*C. tripos.*	*C. macroceros.*	*C.* spp. unidentified.	*Podolampas.*	*Blepharocysta.*	Dinospores.	*Pontosphaera haeckeli.*	*Syracosphaera pulchra.*	*Calyptrosphaera oblonga.*	*Discosphaera tubifer.*	*Rhabdosphaera stylifer.*	*Distephanus.*	*Dictyocha.*	Euglenid flagellates.	Unidentified flagellates.	Amoeba.	Foraminifera.	Radiolaria.	*Tintinnopsis* spp.	*Codonellopsis.*	*Protorhabdonella.*	*Rhabdonella.*	*Dictyocysta.*	*Amphorella.*	*Amphorellopsis* and *Steenstrupiella.*	*Dadayiella.*	*Tintinnus.*	Unidentified Tintinnids.	Naked ciliates.	Unidentified cells.	Green algal cells.	Gelatinous colonies of algal cells.	*Trichodesmium.*	Copepod nauplii.	Copepods.	Ostracods.	Nematodes.	Polychaete larvae.	Other worms.	Echinoderm larvae.	*Cyphonautes* larvae.	Lamellibranch larvae.	Unidentified larvae.	Appendicularia.	Eggs.
..	..	10	30	..	10	10	..	10	..	..	..	..	..	..	..	..	..	..	..	10	..	240	..	..	..	..	380	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
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5	35	50	30	5	10	..	..	..	5	5	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	10	20	25	..	..	..	95	10	5	..	..	..	..	..	..	..	..	20	..
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TABLE V.

Date (1928–29).	Time.	Depth in metres.	Total diatoms.	Total dinoflagellates.	*Paralia.*	*Skeletonema.*	*Thalassiosira.*	*Hyalodiscus.*	*Coscinodiscus.*	*Planktoniella.*	*Asteromphalus.*	*Rhizosolenia.*	*R. stolterforthii.*	*Corethron.*	*Bacteriastrum.*	*Chaetoceros.*	*Hemiaulus.*	*Climacodium biconcavum.*	*C. frauenfeldianum.*	*Cerataulina.*	*Biddulphia.*	*Ditylium.*	Pennate diatoms.	*Nitzschia closterium.*	*Leptocylindrus*, large form.	*Leptocylindrus*, small form.	Unidentified diatoms.	*Pronoctiluca.*	*Amphidinium.*	*Gymnodinium* spp., colourless.	*G.* spp., green.	*Gyrodinium.*	*Cochlodinium.*	*Pouchetia.*	*Exuviella.*	*Prorocentrum.*
Aug. 1	..	2	3510	1430	..	..	..	..	10	..	..	70	30	..	20	120	..	110	..	..	..	..	2050	970	..	..	130	..	30	1310	30	..	10	..	..	..
,, 3	..	2	4370	1650	230	..	..	..	10	..	..	470	..	..	10	110	110	..	..	..	..	..	3260	..	..	..	170	..	30	1480	..	..	..	..	..	..
,, 9	10.00 a.m.	2	5540	1810	300	..	..	..	10	..	10	190	220	..	100	370	80	..	..	30	..	..	3300	920	..	..	10	10	20	1520	..	..	10	..	..	..
,, 10	10.10 ,,	2	5180	2570	800	..	..	..	10	..	..	180	10	..	..	110	..	..	..	10	..	..	2740	1280	..	..	40	..	30	2300	40	..	..	..	..	..
* ,, 13	9.00 ,,	2	6810	1510	..	..	..	..	40	..	..	60	30	..	10	60	10	..	..	..	..	..	4080	2500	..	..	20	..	20	1280	50	..	..	..	..	..
,, 15	9.55 ,,	2	10640	2050	540	..	..	..	10	..	..	440	100	..	20	190	30	100	..	100	10	..	5270	3800	..	..	30	..	20	1610	120	..	..	..	10	..
,, 17	9.40 ,,	2	8190	1260	..	..	..	..	40	..	..	580	180	..	90	430	230	240	..	140	..	..	4500	1530	..	..	230	..	30	1000	50	..	20	..	20	..
,, 20	8.45 ,,	2	8410	2570	40	..	..	..	10	..	..	760	360	..	170	1130	40	60	..	..	..	..	4150	1530	..	..	160	10	80	1970	160	10	10	..	20	..
,, 21	8.45 ,,	2	9810	1300	80	..	..	..	10	..	..	1070	260	..	790	2200	140	350	..	90	..	..	3350	840	..	..	630	..	30	960	60	20	..	..	..	..
,, 27	8.40 ,,	2	5850	1730	140	..	..	..	10	..	..	100	10	..	50	230	80	60	40	..	..	..	3090	2000	..	..	40	..	30	1520	..	..	..	..	..	..
,, 28	9.30 ,,	2	11300	2150	..	..	..	..	10	..	..	280	110	..	120	2640	650	30	..	40	..	..	3910	2440	..	..	1070	70	30	1160	80	..	20	..	..	..
,, 29	9.00 ,,	2	28300	1210	..	..	..	..	10	..	..	890	120	..	150	9500	1070	..	..	170	..	..	6910	7200	..	2210	70	10	10	630	70	..	..	..	..	..
,, 30	10.00 ,,	2	167400‡	1090	250	..	..	..	50	..	..	4000	750	..	2550	118000	5500	300	..	200	50	..	16700	9000	..	10000	50	60	20	550	80	20	10	..	..	..
Sept. 3	9.15 a.m.	2	5240	1940	..	..	..	..	..	..	10	520	130	..	220	570	60	..	..	10	..	..	2930	560	..	230	..	..	50	1580	40	..	..	..	..	10
,, 8	10.15 ,,	2	5240	790	..	..	..	..	..	..	..	550	130	..	230	670	120	..	..	120	..	..	2140	1070	..	190	20	..	10	590	50	..	10	..	..	..
,, 10	9.10 ,,	2	6460	1290	..	..	..	..	10	..	..	430	60	..	270	650	340	..	..	70	..	..	2860	470	..	1230	70	30	50	1000	50	10	..	10	..	..
,, 13	9.35 ,,	2	7000	940	..	..	..	..	..	..	..	350	70	..	100	360	360	80	40	..	..	..	4000	1400	..	240	..	..	30	690	40	..	20	..	..	..
,, 15	9.30 ,,	2	7940	1170	180	..	..	..	10	..	..	360	90	..	30	260	240	..	..	50	..	..	4440	2100	..	180	..	20	..	860	50	..	40	10	..	..
,, 16	10.00 ,,	2	5320	1190	..	..	..	..	..	..	..	440	20	..	30	340	150	60	..	..	..	..	2690	1460	..	20	110	..	40	820	140	10	..	..	..	..
,, 17	9.45 ,,	2	3490	970	200	..	..	..	..	..	..	220	..	..	100	170	180	..	..	..	..	..	1690	690	..	240	..	..	10	610	130	..	10	..	..	..
,, 22	8.55 ,,	2	2460	940	..	..	..	..	..	..	..	10	..	..	20	60	..	..	..	..	..	..	1410	940	..	20	..	..	60	750	20	..	..	..	..	..
,, 25	9.35 ,,	2	5300	510	50	..	..	..	..	..	..	20	..	..	..	30	..	..	..	..	..	..	3050	2150	..	..	..	..	..	380	20	10	..	..	..	..
,, 28	6.50 ,,	2	4620	410	360	..	..	..	30	..	..	50	..	..	..	30	..	..	..	..	..	..	2860	1290	..	..	..	10	..	250	40	..	10	..	..	..
Oct. 4	6.45 a.m.	2	1870	1360	..	..	..	..	..	..	..	10	50	..	160	430	10	..	..	..	..	..	930	280	..	..	..	20	..	1090	50	..	30	..	..	10
,, 8	9.30 ,,	2	1220	1150	..	..	..	..	20	..	..	40	..	..	40	60	..	..	..	..	..	..	750	310	..	..	..	..	50	860	30	..	..	10	..	..
,, 10	7.30 ,,	2	4950	510	400	..	..	..	10	..	..	..	..	..	150	40	160	..	..	..	..	..	2820	1370	..	..	..	..	10	320	20	..	20	..	..	..
,, 12	3.45 p.m.	2	5030	740	50	60	..	..	20	..	..	30	30	..	40	470	..	..	..	..	..	..	2390	1870	..	70	..	20	10	570	40	..	..	..	..	..
,, 15	9.00 a.m.	2	4080	1140	..	..	..	..	10	..	..	10	10	..	..	40	..	530	..	..	..	..	2360	960	..	160	..	20	60	810	90	..	..	..	..	10
,, 18	7.30 ,,	2	1930	890	..	..	..	..	..	..	..	50	10	..	40	..	..	30	..	..	..	..	1470	330	..	..	..	20	..	700	30	..	30	10	..	..
,, 24	9.00 ,,	2	4280	650	440	..	..	..	..	..	..	110	60	..	20	..	..	..	..	..	..	..	2430	1080	..	140	..	30	10	440	30	..	..	..	..	..
,, 27	9.00 ,,	2	2750	1300	..	..	..	..	..	..	10	260	110	..	300	320	..	20	..	..	..	..	1470	80	..	180	..	..	..	1070	50	..	10	..	10	10
,, 29	6 30 ,,	2	820	960	..	..	..	..	..	..	..	40	20	..	10	110	..	..	..	..	..	..	540	60	..	40	..	..	30	760	30	..	..	..	..	..
Nov. 1	9.20 a.m.	2	690	970	..	..	..	..	..	..	10	20	..	..	50	50	..	..	..	..	..	..	460	40	..	40	20	..	50	840	10	30	..	10	..	..
,, 2	7.00 ,,	2	1700	1230	60	40	..	..	..	..	..	..	10	..	..	100	..	..	..	..	..	..	1160	230	..	100	..	10	..	980	60	..	..	10	..	..
,, 5	6 30 ,,	2	370	1920	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	240	110	..	..	..	..	40	1650	150	..	10	..	10	..
,, 8	7.15 ,,	2	1700	1360	..	..	..	..	..	..	..	50	20	..	..	30	..	..	..	..	..	..	1040	520	..	40	..	..	50	1060	170	..	..	..	..	..
* ,, 10	9 00 ,,	2	4830	540	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3450	1380	..	..	..	..	40	260	110	..	..	..	..	10
† ,, 12	4.15 p.m.	2	8900	310	100	..	..	..	30	..	..	..	..	..	..	1720	..	..	..	..	..	..	4060	2940	..	..	50	..	10	100	100	..	..	..	..	..
† ,, 14	9.15 a.m.	2	14090§	180	1150	..	50	20	20	..	..	40	..	..	..	140	..	..	..	..	..	..	8300	4260	..	110	..	..	..	70	80	..	..	..	..	..
,, 16	9.00 ,,	2	16220‖	690	110	..	..	..	70	..	..	90	60	..	1940	4940	100	10	..	520	..	50	4580	900	2840	..	10	..	10	190	250	..	..	..	..	10
,, 22	7.45 ,,	2	3600	590	..	..	..	..	40	..	..	20	90	..	..	100	..	..	..	20	..	..	2400	930	..	..	..	..	10	420	80	..	..	..	..	..
,, 27	7.15 ,,	2	820	1040	..	..	..	..	..	..	20	60	..	..	..	10	..	..	..	20	..	..	630	80	..	..	..	..	10	840	80	..	10	10	..	..
,, 30	6.45 ,,	2	2500	690	40	..	..	..	60	..	..	40	90	..	..	..	..	..	..	..	..	..	1370	240	..	660	..	..	..	290	240	..	..	..	..	..
Dec. 3	6.00 a.m.	3	1150	1520	30	..	..	..	20	..	10	10	..	..	..	..	..	20	..	..	..	..	710	210	120	20	..	..	20	850	300	..	20	..	..	..
,, 5	7.15 ,,	3	2540	890	..	..	..	..	10	..	..	60	40	..	..	80	..	..	..	..	..	..	1800	210	300	40	..	..	10	600	100	..	..	..	10	..
* ,, 7	7.30 ,,	2	2840	680	250	..	..	..	40	..	..	60	30	..	..	150	..	..	..	70	10	..	1730	350	150	..	..	..	20	420	60	..	30	..	..	..
,, 10	7 00 ,,	2	3010	2320	40	..	..	..	30	..	10	130	140	..	410	190	..	..	..	..	..	..	1720	270	..	70	..	20	40	1540	280	40	50	10	10	..
* ,, 12	9.30 ,,	2	5700	760	..	..	..	..	20	..	..	70	40	..	..	100	..	..	..	30	..	..	4220	1220	..	..	..	..	10	490	210	..	..	..	..	..
,, 15	6.15 ,,	2	4290	800	30	..	..	..	50	..	..	70	60	..	210	140	..	..	..	20	..	..	2950	590	50	120	..	..	10	510	70	..	..	..	..	20
,, 17	8.45 ,,	2	4460	1090	40	..	..	..	20	..	10	80	160	10	180	410	20	..	..	..	10	..	1710	720	970	120	..	..	20	830	110	10	..	..	..	..
,, 21	6.30 ,,	2	4670	900	40	..	..	..	20	..	..	280	10	..	50	540	..	30	..	130	..	..	3030	300	190	30	20	10	..	660	40	..	..	10	..	..
,, 24	5.45 ,,	2	1820	950	..	..	..	..	30	..	10	30	30	..	40	160	..	..	..	10	..	..	1360	100	30	20	..	30	10	600	70	10	..	..	..	10
,, 26	10.30 ,,	2	2350	1210	..	..	..	..	..	..	10	290	30	..	180	350	..	350	..	40	..	..	650	60	250	140	..	10	20	690	100	..	..	20	..	..
Jan 9	3 00 p m	2	7440	490	..	..	..	..	70	..	..	90	120	..	430	1660	170	100	..	330	..	..	2910	1340	180	..	40	..	..	230	160	..	..	..	..	..
,, 12	9.30 a.m.	2	5130	2290	40	..	..	..	70	..	..	30	..	..	370	610	20	..	..	70	10	..	2280	1100	490	20	20	30	10	1600	450	..	..	..	..	..
,, 15	9.30 ,,	2	950	190	..	..	..	..	..	..	..	40	..	..	30	100	..	..	..	10	..	..	610	160	..	..	..	..	..	170	10	..	..	..	..	..
,, 17	9.40 ,,	2	1360	300	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	880	460	..	..	..	..	..	240	..	..	..	10	..	..
,, 23	9.30 ,,	2	1860	1320	..	..	..	..	..	..	..	10	..	..	..	230	..	..	..	..	..	..	1400	220	..	..	..	10	10	800	220	20	20	..	..	..
,, 26	10.00 ,,	2	6020	1580	..	..	..	..	20	..	..	70	40	..	800	1210	20	..	..	..	..	..	2750	770	310	..	30	..	..	940	270	10	20	..	..	..
,, 28	7.45 ,,	2	10510	530	200	..	..	..	30	..	..	190	40	..	2340	3880	50	40	60	..	..	..	1210	120	2350	..	..	..	..	210	120	..	..	..	..	..
Feb. 1	6.30 a.m.	2	2400	1090	..	..	..	..	10	..	10	30	20	..	290	220	..	..	..	80	..	..	1420	60	260	..	..	30	60	790	60	..	..	10	..	..
,, 4	10.30 ,,	2	2220	750	..	..	..	..	30	..	..	10	10	..	..	10	..	..	..	..	..	..	1670	380	110	..	..	..	10	550	90	10	..	..	..	..
,, 7	7.00 ,,	2	4990	680	100	..	..	..	30	..	..	10	30	..	..	110	..	20	..	..	..	..	3870	820	..	..	..	..	10	580	80	..	..	..	..	..
,, 10	7 45 ,,	2	580	450	..	..	..	..	..	..	..	..	..	..	10	70	20	..	..	..	..	..	470	10	..	..	..	..	..	350	60	..	..	..	..	..
,, 15	11.50 ,,	2	1480	1120	..	..	..	..	10	..	..	80	..	..	..	60	..	80	..	..	..	..	700	100	450	..	..	..	20	900	130	10	..	..	..	..
,, 20	7.30 ,,	2	770	570	..	..	..	..	..	..	..	10	..	..	..	30	..	60	..	..	..	..	610	..	60	..	..	..	..	460	50	..	..	..	10	..

* Sample taken nearer the island than usual, near Wishart's Reef. † Sample taken in the Anchorage. ‡ Diatoms counted in 20 c.c. only.

TABLE V.

Phalacroma	*Dinophysis*	*D. caudata.*	*Ceratocorys*	*Ornithocercus.*	*Amphisolenia.*	*Gonyaulax*	*Diplopsalis* type.	*Peridinium* spp.	Thecate, colourless peridinians.	Thecate, green peridinians.	*Pyrophacus.*	*Oxytoxum* spp.	*O. scolopax*	*Ceratium candelabrum.*	*C. kofoidii.*	*C. furca* subsp. *eugrammum.*	*C. teres*, etc.	*C. fusus.*	*C. pennatum.*	*C. tripos*	*C. macroceros.*	*C.* spp. unidentified.	*Podolampas*	*Blepharocysta.*	Dinospores.	*Pontosphaera huxleyi.*	*Syracosphaera pulchra.*	*Calyptrosphaera oblonga.*	*Discosphaera tubifer.*	*Rhabdosphaera stylifer.*	*Distephanus.*	*Dictyocha*	Euglenid flagellates.	Unidentified flagellates.	Amoeba.	Foraminifera	Radiolaria.	*Tintinnopsis* spp.	*Codonellopsis.*	*Protorhabdonella*	*Rhabdonella.*	*Dictyocysta*	*Amphorella.*	*Amphorellopsis* and *Steenstrupiella.*	*Dadayiella.*	*Tintinnus.*	Unidentified Tintinnids.	Naked ciliates.	Unidentified cells.	Green algal cells.	Gelatinous colonies of algal cells.	*Trichodesmium*	Copepod nauplii.	Lamellibranch larvae.	Appendicularia.
..	..	..	..	..	..	10	..	..	..	30	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..
10	..	..	..	..	..	..	10	10	20	10	..	..	..	..	40	..	..	20	..	10	10	..	..	..	..	..	..	..	..	..	..	..	..	2460	..	..	..	..	..	..	..	..	..	..	..	..	40	50	..	..	..	..	..	..	..
..	..	..	..	..	..	20	..	..	80	30	..	..	..	..	110	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	360	..	..	..	..	..	..	..	..	..	..	..	..	40	20	20	..	50	170	..	..	..
..	..	..	..	..	..	..	..	10	20	10	..	..	..	..	70	..	..	10	..	..	..	..	30	..	50	..	..	..	..	..	..	..	..	850	..	..	..	..	..	..	..	..	..	..	..	..	40	40	..	..	20	10	..	..	..
..	..	..	..	..	..	..	..	..	10	20	..	..	..	..	70	..	..	..	..	..	..	..	10	..	40	..	..	..	..	..	..	..	..	1000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	10	..	..	..
..	..	..	..	..	..	..	..	30	40	..	..	..	..	..	140	10	..	..	10	20	..	..	..	..	40	..	..	..	..	..	..	..	..	2800	..	..	..	..	..	..	20	..	..	..	..	10	..	..	10	..	10	10	10	..	..
10	..	..	..	..	..	..	..	20	..	..	..	..	..	..	20	..	..	20	..	..	10	20	..	..	40	..	..	10	..	..	..	..	..	710	..	..	10	..	..	20	..	..	..	..	..	10	30	40	10	..	..	330	..	..	..
10	..	..	..	..	..	..	..	80	20	30	..	..	..	..	100	10	..	..	10	..	10	..	10	..	30	..	..	10	10	..	..	..	..	1860	..	..	..	..	..	10	..	..	..	..	..	..	20	20	10	..	..	10	..	..	..
..	..	..	..	..	..	..	..	60	50	10	..	..	..	..	40	20	..	10	..	10	20	..	..	..	10	..	..	..	..	..	..	..	..	450	..	..	10	..	..	20	..	..	..	..	..	10	10	10	20	..	..	..	10	..	..
..	..	..	..	..	..	..	..	30	40	30	..	..	..	..	60	..	10	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	610	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	10	..	..
10	..	..	..	..	..	10	10	130	200	70	10	..	..	..	170	10	20	10	..	..	..	..	..	..	140	20	..	..	..	..	..	..	..	570	..	..	..	..	..	10	..	..	10	..	..	10	30	..	40	..	..	220	10	..	..
20	..	..	..	..	..	10	100	80	160	50	..	..	..	..	50	10	..	..	..	..	..	..	10	..	10	..	..	..	..	..	..	..	..	630	..	..	10	..	..	..	..	..	..	..	..	..	..	10	10	..	..	500	..	..	20
..	..	..	..	..	..	..	30	80	60	40	..	..	..	..	90	..	..	..	..	..	..	..	..	..	50	..	..	..	..	..	..	..	..	1410	..	..	..	..	..	..	..	..	..	..	..	..	..	..	30	..	..	..	..	10	..
..	..	..	..	..	..	20	..	..	90	20	..	..	..	..	70	20	..	30	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	800	..	..	..	..	..	10	..	..	..	..	..	..	20	10	40	..	..	100	..	..	..
..	..	..	..	..	..	..	10	20	50	10	..	..	..	..	20	..	10	10	..	..	..	..	..	..	..	10	..	10	20	..	..	..	..	90	..	..	30	..	10	..	..	..	..	..	..	..	10	..	20	..	..	..	10	..	..
10	..	..	..	..	..	..	10	..	40	10	..	10	..	..	20	30	..	..	..	..	..	..	..	..	10	..	10	..	..	..	..	..	..	160	..	..	..	..	..	..	..	..	..	..	..	..	..	..	60	200	..	..	..	..	..
..	..	..	..	..	..	10	30	30	10	..	..	..	..	..	40	10	..	10	..	..	20	..	..	..	..	..	10	..	20	..	..	..	..	210	..	..	10	..	10	..	..	..	..	..	..	..	..	..	60	..	..	..	..	..	..
..	..	..	..	..	..	..	..	30	10	60	..	..	..	..	..	10	10	..	..	..	..	..	10	..	60	..	..	..	20	..	..	..	..	300	..	..	10	10	..	..	..	..	..	..	..	..	..	..	40	..	..	..	..	..	10
..	..	..	..	..	..	..	30	10	40	30	..	..	..	..	30	..	..	..	..	..	..	..	..	..	40	..	..	..	10	..	..	..	..	440	..	..	..	..	..	..	..	..	..	..	..	..	..	30	..	..	..	10	..	..	..
10	..	..	..	..	..	..	60	20	10	20	..	10	..	..	10	..	..	20	..	..	..	..	..	..	50	..	..	..	..	..	..	..	..	430	..	..	..	..	..	10	..	..	10	..	..	..	10	50	..	..	..	..	..	..	..
10	..	..	..	..	..	..	..	10	20	50	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	20	..	..	40	10	..	..	..	260	..	..	..	..	..	..	..	..	20	..	..	10	..	10	20	..	..	..	..	..	..
..	..	..	..	..	..	..	..	30	50	..	..	..	..	..	10	..	..	10	..	..	..	..	..	..	..	20	..	..	10	..	..	..	..	100	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	40	10	..	..	..	..	..	30	..	10	..	..	..	..	..	..	..	10	..	..	..	20	..	..	..	..	190	..	..	10	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	10
..	..	..	..	..	..	..	..	30	30	30	..	..	..	..	30	10	20	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	280	..	..	..	..	..	..	..	..	10	..	..	10	10	..	40	..	..	30	10	..	..
..	..	..	..	..	..	..	..	10	70	70	..	10	..	..	..	..	10	..	..	..	..	..	10	..	20	..	..	..	..	..	..	..	..	190	..	..	10	..	..	..	..	..	..	..	..	..	..	10	30	..	..	10	..	..	..
10	..	..	..	..	..	..	10	10	80	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	10	20	..	..	10	..	..	..	..	140	..	..	10	..	..	..	..	..	..	..	..	..	10	10	10	..	..	..	..	..	10
..	..	..	..	..	..	..	20	10	20	..	..	..	..	..	10	20	..	10	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	300	..	..	..	..	..	..	..	..	..	..	..	..	..	40	..	..	..	..	..	..	10
10	..	..	..	..	..	10	30	..	60	10	..	..	..	..	20	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	360	..	..	..	..	..	..	..	..	..	..	..	..	..	20	20	..	..	..	..	..	..
10	..	..	..	..	..	..	10	..	70	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	480	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20	..	..	..	..	..	..	..	30	10	20	..	..	10	..	30	..	10	10	..	..	..	..	..	..	..	30	..	..	20	..	..	..	..	70	..	..	..	..	..	..	..	..	..	..	..	..	..	20	10	..	..	10	..	20	..
..	..	..	..	..	..	..	10	40	70	20	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	10	..	..	340	..	..	40	..	..	..	..	..	..	..	..	..	10	30	10	..	..	..	..	..	..
..	..	..	..	..	..	10	..	30	20	20	..	10	..	..	..	50	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	460	..	..	..	..	..	..	..	..	10	..	..	..	..	20	10	..	..	..	20	..	..
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..	..	..	..	..	..	..	..	30	60	10	..	20	10	..	30	..	..	..	..	..	..	..	..	..	10	10	..	..	..	..	..	..	..	220	..	..	20	..	..	..	..	..	..	..	..	..	..	40	10	..	..	80	..	..	..
..	..	..	..	..	..	..	..	..	..	30	..	10	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	340	..	..	10	..	..	..	..	..	..	..	..	..	..	720	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	20	30	..	..	..	..	20	..	..	..	..	..	..	..	..	..	10	..	..	..	10	..	..	..	..	300	..	..	..	..	..	..	..	..	..	..	..	..	20	320	..	..	..	10	..	..	..
..	..	..	..	..	..	..	..	10	60	30	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	380	10	..	..	..	..	..	..	..	..	..	..	..	..	160	20	..	..	60	..	..	..
..	..	..	..	..	..	..	..	10	30	20	..	20	..	..	10	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	570	..	..	..	..	..	..	..	..	..	..	..	..	..	860	30	..	..	80	..	..	10
..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	290	..	..	..	..	..	..	..	..	..	..	..	..	..	30	..	..	..	10	..	..	..
..	..	..	..	..	..	..	30	20	50	30	..	..	..	..	..	..	..	40	10	..	..	..	..	10	40	..	..	..	..	..	..	10	..	430	..	..	30	..	..	..	..	..	..	..	..	..	..	130	..	50	..	10	20	..	..
..	..	..	..	..	..	..	30	..	10	..	..	10	..	..	10	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	80	..	..	10	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..
..	..	..	..	..	..	..	10	20	10	..	..	20	..	..	10	..	..	..	..	..	..	..	10	10	..	..	..	..	..	..	..	..	..	330	..	..	..	..	..	..	..	..	..	..	..	..	..	750	..	..	..	..	..	..	..
..	..	..	..	..	..	..	10	40	10	..	..	10	..	..	10	..	..	10	..	..	..	..	..	10	60	..	..	10	..	..	..	20	..	200	..	..	..	..	..	..	..	..	..	..	..	10	10	10	..	..	..	..	..	..	..
..	..	..	..	..	..	..	30	40	120	40	..	..	..	..	10	10	..	20	..	..	..	..	10	30	20	..	..	..	..	..	..	..	..	160	..	..	..	..	..	..	..	..	20	..	..	..	20	..	20	..	..	..	..	..	..
..	..	..	..	..	..	..	10	40	..	10	..	..	..	..	20	10	..	10	..	..	..	..	..	10	60	..	..	..	..	..	..	..	10	140	..	..	30	..	10	..	..	..	..	..	..	..	10	70	10	110	..	..	..	..	10
10	..	..	..	..	..	..	..	30	40	..	..	10	..	..	10	..	..	30	..	..	..	..	..	..	20	..	..	..	..	..	..	..	10	200	..	..	..	..	..	..	..	..	..	..	..	..	..	30	..	80	..	..	..	..	..
..	..	..	..	..	..	20	20	160	40	20	..	10	..	..	20	10	..	20	..	..	..	..	..	..	70	..	..	..	..	..	..	..	..	360	..	..	10	..	..	..	..	..	..	..	..	..	20	120	..	..	340	..	..	..	20
..	..	..	..	..	..	..	..	40	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	660	..	..	20	..	..	..	..	..	..	..	..	..	..	..	30	80	..	20	..	..	10
..	..	..	..	..	..	..	10	50	60	10	10	..	..	..	20	..	..	..	..	..	..	..	..	10	20	..	..	..	..	..	..	..	..	180	10	..	20	..	..	..	..	..	10	..	..	..	..	30	..	420	..	10	..	..	..
..	..	..	..	..	..	10	..	50	20	10	..	..	..	..	10	10	..	10	..	..	..	..	..	10	..	..	..	..	..	..	..	..	10	210	..	..	..	..	..	..	..	..	..	..	..	..	..	40	..	460	..	..	..	..	..
20	..	..	..	..	..	10	..	40	..	20	..	..	40	10	20	..	..	10	..	..	..	..	..	10	..	10	..	10	..	..	..	..	..	440	..	..	20	..	..	..	..	..	..	..	10	..	..	30	..	650	..	..	..	..	..
..	..	..	..	..	..	..	..	50	30	10	10	10	..	..	20	..	..	10	..	..	..	..	10	10	60	..	..	..	..	..	..	..	10	90	..	..	10	..	..	..	..	..	..	..	10	..	..	10	30	..	..	70	10	..	..
..	..	..	..	..	..	..	10	90	70	70	..	..	..	..	60	..	..	50	..	..	..	..	..	10	10	..	..	..	..	..	..	..	10	120	..	..	..	..	..	..	..	..	40	..	..	..	..	..	..	140	..	50	..	..	..
..	..	..	..	..	10	..	..	60	10	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	10	..	420	..	..	50	..	..	..	..	..	10	..	..	..	..	10	20	..	..	..	..	10	..
..	..	..	..	..	..	..	..	40	30	40	..	30	..	..	10	..	..	20	..	..	..	..	..	..	30	..	..	..	..	..	..	..	..	470	..	..	10	..	..	..	..	..	..	..	..	..	..	180	..	..	100	..	20	..	..
..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	60	..	..	10	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	10	..	..
..	..	..	..	..	..	..	..	10	10	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	140	..	..	10	..	..	..	..	..	..	..	..	..	..	200	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	40	70	30	..	20	..	..	..	..	..	..	..	..	..	..	..	..	80	..	..	..	..	..	..	..	..	270	..	..	..	..	..	..	..	..	..	..	..	..	..	120	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	70	130	60	..	..	10	..	30	10	..	..	..	..	..	..	..	..	30	..	..	..	..	..	..	30	..	260	..	..	..	..	..	..	..	..	..	..	..	10	20	70	..	..	..	20	..	10	..
..	..	..	..	..	..	10	..	70	50	30	..	20	..	..	10	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	10	..	50	..	..	10	..	..	..	..	..	10	..	..	..	10	..	..	..	..	30	10	..	..
..	..	..	..	..	..	..	10	10	50	30	..	10	..	..	10	..	..	..	..	10	..	..	..	..	10	..	..	..	..	..	..	..	10	240	..	..	40	..	10	..	..	..	..	..	..	..	..	40	..	200	..	70	..	..	..
..	..	..	..	..	..	..	10	20	10	..	..	10	..	..	10	..	..	..	..	..	..	..	..	..	30	..	..	..	..	..	..	10	10	430	..	..	10	..	..	..	..	..	..	..	..	..	..	30	..	..	..	120	..	..	..
..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	1240	..	..	..	..	..	..	..	..	10	..	..	..	..	150	10	70	..	80	..	..	..
..	..	..	..	..	..	..	..	10	20	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	120	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	220	10	..	..
..	..	20	..	..	..	..	..	20	..	10	..	..	..	..	..	..	..	10	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	520	10	..	20	..	..	..	..	..	..	..	..	..	..	50	..	200	..	..	10	..	..
..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	10	..	..	10	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	160	30	..	10	..	..	..	..	..	10	..	10	10	..	50	50	..	..	150	20	..	..

§ Pennate diatoms counted in 50 c.c. only. ‖ Pennate diatoms, *Chætoceros*, *Bacteriastrum*, and *Leptocylindrus* counted in 50 c.c. only.

TABLE V—(*continued*).

Date (1929).	Time.	Depth in metres.	Total diatoms.	Total dinoflagellates.	*Paralia.*	*Skeletonema.*	*Thalassiosira.*	*Hyalodiscus.*	*Coscinodiscus.*	*Planktoniella.*	*Asteromphalus.*	*Rhizosolenia.*	*R. stolterforthii.*	*Corethron.*	*Bacteriastrum.*	*Chaetoceros.*	*Hemiaulus.*	*Climacodium biconcavum.*	*C. frauenfeldianum.*	*Cerataulina.*	*Biddulphia.*	*Ditylium.*	Pennate diatoms.	*Nitzschia closterium.*	*Leptocylindrus*, large form.	*Leptocylindrus*, small form.	Unidentified diatoms.	*Pronoctiluca.*	*Amphidinium.*	*Gymnodinium* spp., colourless.	*G.* spp., green.	*Gyrodinium.*	*Cochlodinium.*	*Pouchetia.*	*Exuviella.*	*Prorocentrum.*
Mar. 4	9.00 a.m.	2	4510	600	..	..	..	..	20	..	..	40	100	..	210	980	..	40	120	..	..	..	2330	510	80	..	80	..	..	440	70	..	..	..	..	..
,, 9	7.30 ,,	2	1250	690	..	..	..	..	..	..	..	40	..	..	10	10	..	150	..	..	..	..	1020	10	..	..	10	..	20	610	10	..	..	..	..	10
† ,, 12	10.30 ,,	2	5980	120	130	..	..	..	30	..	10	50	..	..	..	50	..	..	..	..	..	..	4630	1080	..	..	..	..	10	100	..	..	..	..	..	..
,, 17	7.15 ,,	2	3320	530	..	..	..	..	40	..	10	30	..	..	70	340	..	..	..	..	20	..	2220	500	90	..	..	..	..	340	40	..	..	..	..	..
* ,, 22	11.30 ,,	2	6890	150	..	..	..	..	10	..	20	100	80	..	250	490	..	..	..	..	..	..	4530	1190	220	..	..	..	..	120	..	..	..	..	..	..
,, 25	8.45 ,,	2	9370	550	..	..	..	..	70	..	20	70	50	..	110	540	70	10	..	..	..	..	6290	1790	140	210	..	..	20	430	30	..	..	..	..	..
,, 28	7.45 ,,	2	4950	520	320	..	..	..	50	..	20	20	70	..	110	540	40	40	..	..	..	..	2390	810	540	..	..	..	..	380	50	..	..	..	..	..
April 1	12.30 p.m.	2	4860	530	90	..	10	..	70	..	20	90	140	..	20	460	170	50	..	..	..	..	2720	560	460	..	..	10	..	310	140	10	..	..	..	10
,, 8	12.00 noon	2	5080	240	..	40	90	..	130	..	10	150	60	..	260	840	160	110	..	..	..	..	2280	470	480	..	..	..	..	140	70	..	..	..	..	..
,, 11	7.30 a.m.	2	6050	440	..	120	..	..	60	..	..	250	270	..	420	680	60	330	30	20	..	..	3140	450	220	..	..	..	10	260	40	10	..	..	..	..
* ,, 15	8.45 ,,	2	6040	110	50	..	..	..	110	..	10	80	..	..	100	1200	..	40	..	..	..	..	3910	470	60	..	10	..	..	90	..	..	..	..	..	..
* ,, 19	12.15 p.m.	2	9440	360	500	..	20	..	70	..	..	170	110	..	110	590	80	90	20	..	..	..	6240	1320	120	..	..	..	30	220	60	10	..	..	..	..
,, 23	7.30 a.m.	2	2210	560	..	..	..	..	..	..	..	50	220	..	180	210	200	..	110	..	..	..	1190	20	30	..	..	..	10	390	60	..	..	..	10	..
,, 29	7.00 ,,	2	4390	200	150	..	..	..	80	..	..	20	..	..	40	..	..	.	..	..	..	..	3530	570	..	..	..	..	..	160	10	..	..	..	..	..
May 2	7.30 a.m.	2	5480	250	50	..	..	10	40	..	..	20	..	..	120	570	..	..	40	20	..	..	3800	810	..	..	..	..	..	190	10	..	..	..	..	..
,, 6	7.15 ,,	2	3460	340	..	..	..	..	70	..	..	..	..	..	..	..	..	10	..	..	..	..	2640	740	..	..	..	..	10	270	50	..	..	..	..	..
,, 9	7.00 ,,	2	4450	730	..	80	..	..	30	..	..	80	..	..	..	20	20	..	..	..	10	..	3360	850	..	..	..	..	10	600	40	10	..	..	..	..
,, 13	7.15 ,,	2	3830	220	..	..	..	..	..	..	..	60	..	..	10	160	..	..	..	..	..	..	3000	600	..	..	..	..	10	150	40	..	..	..	..	..
,, 16	9.45 ,,	2	6540	560	80	..	20	..	50	..	10	70	..	..	100	370	20	..	..	..	..	..	4090	1690	..	..	40	..	10	400	70	10	..	..	..	..
,, 20	9.10 ,,	2	8940	520	..	..	..	..	30	..	..	20	20	..	..	50	..	..	..	..	..	..	6130	2670	20	..	..	..	20	400	80	..	..	..	..	..
,, 23	6.55 ,,	2	4280	1740	..	..	..	..	10	..	20	60	70	..	200	390	70	..	..	..	..	..	2830	630	..	..	..	..	40	1520	40	10	20	10	..	..
,, 27	7.15 ,,	2	4510	810	280	..	..	..	30	..	10	60	50	..	160	580	60	110	..	..	..	..	2300	870	..	..	..	30	70	530	60	..	10	..	10	..
,, 29	12.15 p.m.	2	6780	1130	70	..	..	..	20	..	10	130	360	..	1040	1370	110	250	..	..	..	..	1930	730	540	..	220	..	20	810	70	..	..	10	40	..
,, 30	7.10 a.m.	2	6440	510	90	..	..	..	40	..	10	110	170	..	830	3280	90	50	..	170	..	..	1050	490	40	..	20	20	10	280	20	10	10	..	..	..
June 3	7.10 a.m.	2	5370	970	120	..	..	..	10	..	..	20	60	..	300	490	10	20	..	..	..	..	3060	1060	210	..	10	20	20	690	90	..	30	..	..	..
,, 10	7.00 ,,	2	4660	1060	..	..	..	..	30	..	10	30	70	..	170	920	30	..	..	..	10	..	2750	630	10	..	..	20	20	750	100	10	..	..	..	..
* ,, 13	9.10 ,,	1	9150	350	.:	..	..	..	10	..	..	20	..	..	..	80	20	10	..	20	..	..	5770	3200	20	..	..	..	30	240	30	10	..	..	..	..
,, 17	7.20 ,,	2	9810	550	..	..	..	..	30	..	..	300	500	..	900	1730	..	70	..	..	30	..	4450	1510	290	..	..	..	20	370	30	10	10	..	..	..
,, 20	7.00 ,,	2	3280	1510	30	..	..	..	30	..	10	110	10	..	90	300	20	..	..	..	..	..	1800	520	360	..	..	10	20	1120	110	..	50	20	..	10
,, 24	8.00 ,,	2	6080	700	..	..	..	..	..	..	..	150	220	..	560	630	30	..	30	100	..	..	2520	1020	820	..	..	..	50	440	80	10	10	..	..	..
July 5	9.30 a.m.	2	5130	620	50	..	..	10	20	..	..	90	120	..	..	40	60	..	..	..	70	..	3040	1610	..	..	20	10	20	450	50	20	..	..	..	..
,, 10	9.15 ,,	2	6050	790	80	..	..	..	..	..	..	640	140	..	370	320	60	650	..	10	..	..	2720	600	460	..	..	..	20	630	50	..	..	10	..	..
,, 15	9.30 ,,	2	6170	1820	60	..	..	..	10	..	..	330	250	..	150	840	30	30	..	180	..	..	3130	890	270	..	..	..	30	1330	90	10	10	10	..	..

* Sample taken nearer the island than usual, near Wishart's Reef. † Sample taken in the Anchorage. ‡ Diatoms counted in 20 c.c. only.

REFERENCES.

ALLEN, W. E. 1927. Quantitative Studies on Inshore Marine Diatoms and Dinoflagellates of Southern California in 1921–1922. Bull. Scripps Instn. Oceanogr. Tech. Ser. I, pp. 19–29 and pp. 31–38, text illust.

—— 1928. Review of Five Years of Studies on Phytoplankton at Southern California Piers 1920–1924 inclusive. Bull. Scripps Instn. Oceanogr. Tech. Ser. I, pp. 357–401, text illust.

BIGELOW, H. B., and LESLIE, M. 1930. Reconnaissance of the Waters and Plankton of Monterey Bay, July, 1928. Bull. Mus. Comp. Zool. Harv. LXX, pp. 427–581, text illust.

BULEY, H. M. 1929. Quantitative Studies on Inshore Diatoms and Dinoflagellates of the California Coast in 1925. Bull. Scripps Instn. Oceanogr. Tech. Ser. II, pp. 181–187, text illust.

FOX, D. 1929. Quantitative Studies on Inshore Marine Diatoms and Dinoflagellates taken at Five Stations on the East Pacific Coast in 1926. Bull. Scripps Instn. Oceanogr. Tech. Ser. II, pp. 189–196, text illust.

GAARDER, T., and GRAN, H. H. 1927. Investigations of the Production of Plankton in the Oslo Fjord. Rapp. Cons. explor. mer. XLII, pp. 48.

GOURRET, P. 1883. Sur les Péridiniens du Golfe de Marseille. Ann. Mus. hist. nat. Marseille. Zoologie, I, No. 8, pp. 1–114, 4 pls., 2 tab.

GRAN, H. H. 1912. Preservation of Samples and Quantitative Determination of the Plankton. Pub. Circ. Cons. explor. mer. No. 62, pp. 15.

—— 1915. The Plankton Production in the North European Waters in the Spring of 1912. Bull. Plankt. Cons. explor. mer, 1912, pp. 5–142, 2 pls., 11 tab., text illust.

—— 1929. Quantitative Plankton Investigations carried out during the Expedition with the "Michael Sars," July–Sept., 1924. Rapp. Cons. explor. mer. LVI [No. 5], pp. 1–50, text illust.

—— 1930. The Spring Growth of the Plankton at Møre in 1928–1929 and at Lofoten in 1929 in Relation to its Limiting Factors. Skr. Norske Vidensk.-Akad. Oslo, Mat-Nat. Klasse, No. 5, pp. 1–77, text illust.

—— and THOMPSON, T. G. 1930. The Diatoms and the Physical and Chemical Conditions of the Sea-water of the San Juan Archipelago. Pub. Puget Sd. Biol. Sta. VII, pp. 169–204, text illust.

TABLE V—(*continued*).

Phalacroma.	*Dinophysis.*	*D. caudata.*	*Ceratocorys.*	*Ornithocercus.*	*Amphisolenia.*	*Gonyaulax.*	*Diplopsalis* type.	*Peridinium* spp.	Thecate, colourless peridinians.	Thecate, green peridinians.	*Pyrophacus.*	*Oxytoxum* spp.	*O. scolopax.*	*Ceratium candelabrum.*	*C. kofoidii.*	*C. furca* subsp. *eugrammum.*	*C. teres,* etc.	*C. fusus.*	*C. pennatum.*	*C. tripos.*	*C. macroceros.*	*C.* spp. unidentified.	*Podolampas.*	*Blepharocysta.*	Dinospores.	*Pontosphaera haeckeli.*	*Syracosphaera pulchra.*	*Calyptrosphaera oblonga.*	*Discosphaera tubifer.*	*Rhabdosphaera stylifer.*	*Distephanus.*	*Dictyocha.*	Euglenid flagellates.	Unidentified flagellates.	Amoeba.	Foraminifera.	Radiolaria.	*Tintinnopsis* spp.	*Codonellopsis.*	*Protorhabdonella.*	*Rhabdonella.*	*Dictyocysta.*	*Amphorella.*	*Amphorellopsis* and *Steenstrupiella.*	*Dadayiella.*	*Tintinnus.*	Unidentified Tintinnids.	Naked ciliates.	Unidentified cells.	Green algal cells.	Gelatinous colonies of algal cells.	*Trichodesmium.*	Copepod nauplii.	Lamellibranch larvae.	Appendicularia.
..	..	..	..	..	..	..	..	90	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	490	20	..	40	..	..	..	..	..	..	..	..	..	10	310	10	60	10	..	..	..	..
..	..	..	..	..	..	..	..	20	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	340	..	..	20	..	..	..	..	..	..	..	..	..	..	40	..	150	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	200	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	40	10	..	..
..	..	10	..	..	..	..	..	70	50	10	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	190	10	..	20	..	..	..	..	..	..	..	..	..	10	80	..	..	..	..	..	..	10
..	..	..	..	..	..	..	..	..	20	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	70	..	..	..	..	..	..	..	..	..	..	..	..	..	100	10	..	..	10	..	..	..
..	..	..	..	..	..	..	..	20	20	10	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	440	10	..	10	..	..	..	..	..	10	..	..	..	10	130	..	..	..	..	..	20	..
..	..	..	..	..	..	..	10	40	30	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	180	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	120	10	..	..
..	..	..	..	..	..	..	10	10	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	150	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	20	..	..	..
..	..	..	..	..	..	..	..	..	10	..	..	10	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	130	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	70	..	..	..	..	..
..	..	..	..	..	..	..	30	40	30	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..	20	10	..	..	..	20	..	..
..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	270	10	..	..	..	..	..	..	..	..	..	..	..	..	70	..	7240	..	40	10	..	10
..	..	..	..	10	..	..	10	10	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	190	..	..	..	..	..	..	..	..	..	..	..	10	..	80	..	..	..	30	..	..	..
..	..	..	..	..	10	10	..	..	20	..	..	10	..	..	10	..	..	..	..	20	10	..	..	..	..	..	..	..	..	..	..	..	..	80	..	..	20	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	10	10	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	190	..	..	10	..	..	..	..	..	..	..	10	..	..	50	20	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	20	..	..	..	..	..	..	..	..	30	..	10	10	..	..	..	..	..	10	..	..	..	..	..	..	..	..	60	..	..	10
..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	300	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	..	..	30	..	..	..
..	..	..	..	..	..	..	..	20	10	10	..	10	..	..	..	..	..	10	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	350	..	..	..	..	..	..	..	..	..	..	..	..	..	30	..	..	..	10	..	..	..
..	..	..	..	..	..	..	..	..	10	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	150	..	..	..	..	..	..	..	..	..	..	..	..	20	30	..	..	..	20	10	..	..
..	..	..	..	..	..	..	..	..	20	20	..	..	..	..	..	..	..	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	260	..	..	..	..	..	..	..	..	10	..	10	..	30	60	..	..	..	..	..	..	..
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§ Pennate diatoms counted in 50 c.c. only. ‖ Pennate diatoms, *Chætoceros*, *Bacteriastrum*, and *Leptocylindrus* counted in 50 c.c. only.

KARSTEN, G. 1907. Das Indische Phytoplankton. Nach dem material der Deutschen Tiefsee-Expedition 1898–1899. Wiss. Ergebn. der Deutschen Tiefsee-Exped. II, Tiel ii, pp. 223–548, pls. xxxv-liv, text illust.

LEBOUR, M. V. 1917. The Microplankton of Plymouth Sound from the Region beyond the Breakwater. J. Mar. Biol. Ass. U.K. XI, pp. 133–182, text illust., 2 tab.

—— 1925. The Dinoflagellates of Northern Seas, pp. v, 250, 35 pls., text illust. Plymouth.

LOHMANN, H. 1908. Untersuchungen zur Feststellung des vollständigen Gehaltes des Meeres an Plankton. Wiss. Meeresuntersuch. N.F., X, Abt. Kiel, pp. 129–370, pls. ix–xvii, tab. A–B, text illust.

—— 1920. Die Bevölkerung des Ozeans mit Plankton nach den Ergebnissen der Zentrifugenfänge während der Ausreise der "Deutschland" 1911. Arch. Biontol. IV, Heft 3, pp. 1–617, 16 pls., text illust.

MARSHALL, S. M., and ORR, A. P. 1927. The Relation of the Plankton to some Chemical and Physical Factors in the Clyde Sea Area. J. Mar. Biol. Ass. U.K. XIV, pp. 837–868, 10 pls., text illust.

—— 1928. The Photosynthesis of Diatom Cultures in the Sea. J. Mar. Biol. Ass. U.K. XV, pp. 321–360, text illust.

MOBERG, E. G. 1928. The Interrelation between Diatoms, their Chemical Environment, and Upwelling Water in the Sea, off the Coast of Southern California. Proc. Nat. Acad. Sci. Wash. XIV, pp. 511–518, text illust.

OSTENFELD, C. H. 1913. De Danske Farvandes Plankton i aarene 1898–1901. Phytoplankton og Protozoer. K. Danske Vidensk. selsk. Skr. Raekke 7 Naturvid. Afd. IX, pp. 113–478, text illust.

—— 1914. Résumé des observations sur le plankton. Bacillariales. Bull. trimestr. Cons. explor. mer. pt. 3, pp. 403–508, illust.

SLEGGS, G. F. 1927. Marine Phytoplankton in the Region of La Jolla, California, during the Summer of 1924. Bull. Scripps Instn. Oceanogr. Tech. Ser. I, pp. 93–117, text illust.

STEIN, F. VON. 1883. Der Organismus der Infusionsthiere, III, 2. Die Naturgeschichte der Arthrodelen Flagellaten. Leipzig, pp. 30, 25 pls.

VERWEY, J. 1931. Coral Reef Studies II. The Depth of Coral Reefs in Relation to their Oxygen Consumption and the Penetration of Light in the Water. Treubia, XIII, pp. 169–198, text illust.

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THE ZOOPLANKTON

II. THE COMPOSITION OF THE ZOOPLANKTON OF THE BARRIER REEF LAGOON

BY

F. S. RUSSELL, D.S.C., B.A., AND J. S. COLMAN, B.A.

III. A COMPARISON OF THE ABUNDANCE OF ZOOPLANKTON IN THE BARRIER REEF LAGOON WITH THAT OF SOME REGIONS IN NORTHERN EUROPEAN WATERS

BY

F. S. RUSSELL, D.S.C., B.A.

WITH ELEVEN FIGURES IN THE TEXT.

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II. THE COMPOSITION OF THE ZOOPLANKTON OF THE BARRIER REEF LAGOON.

By F. S. Russell, D.S.C., B.A., and J. S. Colman, B.A.

In the previous report (Vol. II, No. 2) it was stated that the objects of the plankton research were twofold: "Firstly to study the abundance of the plankton animals throughout a whole year in one locality, and secondly, to obtain as complete a collection as possible of plankton organisms of all sizes to form an adequate basis of our knowledge of the species to be found in the region in which we were working. It was necessary, therefore, to fish with nets of different meshes, and to obtain quantitative data as to the abundance and importance of animals of different sizes. By carefully made collections it was hoped that not only would it be possible to arrive at the seasonal changes in abundance of the different organisms that comprise the plankton, but that also comparative data would be obtained from which some idea could be gained of the richness of the plankton as food for other organisms as compared with data from other parts of the world.

"To this end, not only were oblique hauls employed to ensure large enough catches to give significant results, but vertical hauls through a water column of known depth were also made to give information directly comparable with data obtained elsewhere."

In the present report we deal with the general composition of the plankton and the abundance of the groups as a whole. At the end of the report are tables giving all the catches for the different animal groups collected during the expedition. These include the vertical hauls with the coarse silk net (Table V), the half-hour oblique hauls with the coarse and fine silk nets and the 1-metre stramin net (Tables II, III and IV) from the weekly station three miles east of Low Isles in the Barrier Reef lagoon; the average catches for each month based on these results (Tables IX and X); the collections made at stations other than the weekly station (Table VI); the collections made to study vertical distribution (Table VIII); and the catches made with a small townet at high water over the reef-flat of Low Isles (Tables VII and XI). The details of times of collecting, conditions, etc., have already been published in Vol. II, No. 2, pp. 28 to 35.

It will not be possible here to enter fully into the results of the study of seasonal distribution and its relation to the hydrographical conditions, because for this purpose a closer analysis of the different animal groups is required, and the results will be discussed in another report, when the examinations of all the groups by specialists are completed.

This report will be based mainly on the collections made by the vertical hauls, although, where necessary, the oblique catches will be considered, especially when dealing with the larger animals captured by the stramin net. The report deals only with the zooplankton of the Barrier Reef lagoon.

On the Validity of the Collecting Methods.

In Vol. II, No. 2, p. 8, we said: "There is an added disadvantage, which holds also for the smaller animals, that when the horizontal distribution of the plankton is uneven, due to small swarm formations, the vertically hauled net may only have sufficient time in the water to hit or miss a single swarm; a net towed horizontally for a longer time would hit and miss many swarms and so give a truer picture of the abundance of plankton present."

We hope to show that the data obtained by the vertical hauls should be reliable when taking the groups as a whole, although for the analysis of the species present only the oblique hauls will have obtained sufficient numbers of the less common ones.

In Text-fig. 1 are given the curves for the average catches for each month in the oblique and vertical hauls with the coarse silk net. These curves, which are drawn to the same scale, show a tolerably good agreement, the only anomalies being in January, May, and December or February. When, in Text-fig. 2, we compare the corresponding curves for a single animal group, the Copepoda, the agreement is even closer, the only month in which there is striking disagreement being January. In that month the vertical hauls showed, for some reason, a considerably greater number of copepods than did the

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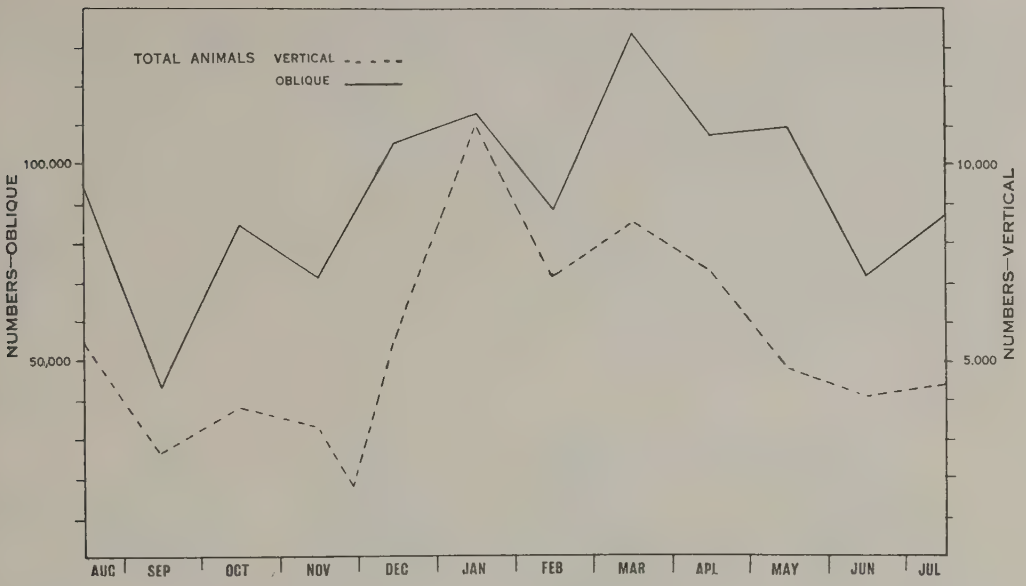
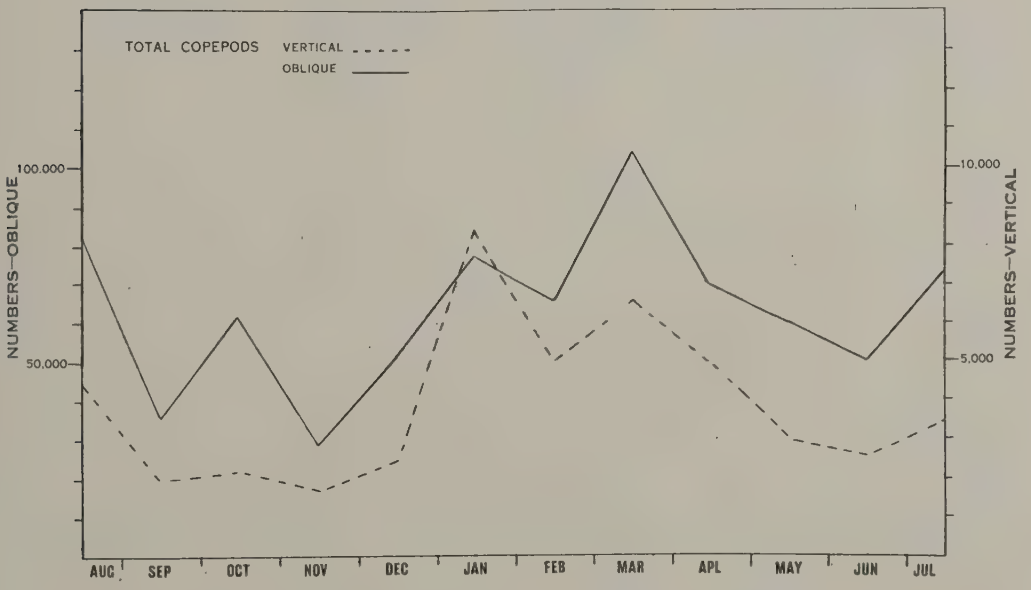


TEXT-FIG. 1.—Curves showing the average catches of all animals for each month in the coarse silk net oblique and vertical hauls at the position three miles east of Low Isles in the Barrier Reef lagoon. Left co-ordinate, numbers in oblique hauls; right co-ordinate, numbers in vertical hauls.



TEXT-FIG. 2.—Curves showing the average catches of copepods for each month in the coarse silk net oblique and vertical hauls at the position three miles east of Low Isles in the Barrier Reef lagoon. Left co-ordinate, numbers in oblique hauls; right co-ordinate, numbers in vertical hauls.

oblique hauls. Since the catches made by fishing the same net in two different ways agree so closely, it seems probable that, when dealing with large numbers, the two methods are almost equally reliable. This is supported by comparisons between the catches and the transparency of the water, which are discussed below.

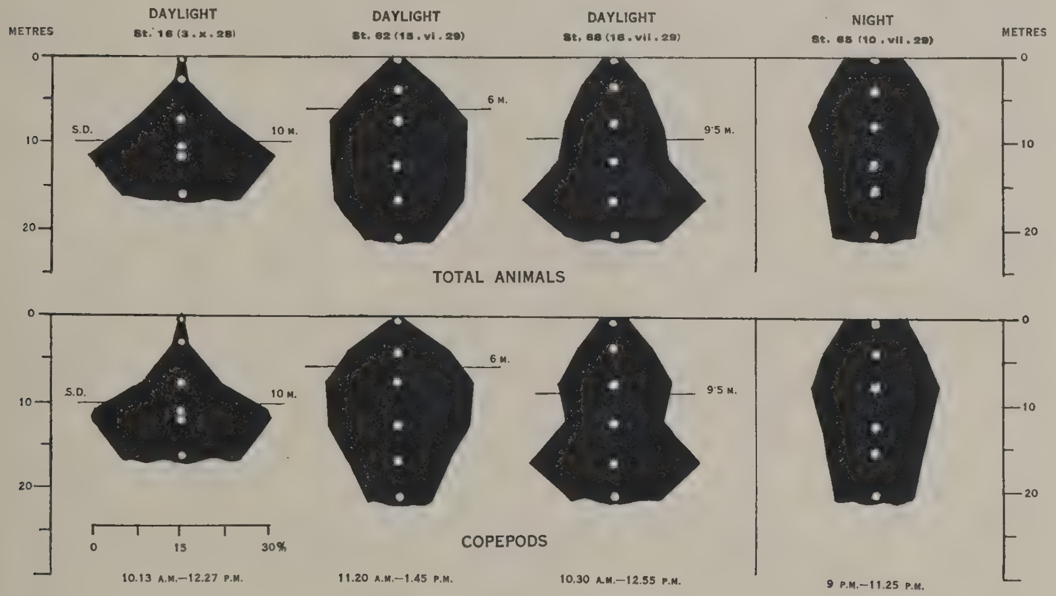
It is somewhat surprising that results with vertical hauls should appear to be so reliable, but Gardiner (1931), who used a silk net with the same mesh as ours, also found them to be so. By examination of a large number of vertical hauls and comparison of some of these with collections by horizontal hauls, he showed that 77% of such vertical hauls might be expected to give values lying within ±33% of the mean (or true) value; of the remainder, one-half would lie within ±40% of the mean, while there would be occasional extreme values up to ±90%.

The Effect of the Transparency of the Water.

Before the work was undertaken it was thought that owing to the bright light conditions and supposed clearness of the water (disproved by Secchi disc observations, see Vol. II, No. 3, p. 46), many, if not most, of the plankton animals might be driven so close to the bottom in the daytime that the usual collecting methods would not sample the whole population. It was thought that all collecting might have to be done at night. Experience of the local conditions soon put ideas of routine night stations out of mind, but before finally abandoning the idea, oblique hauls were made at night to see whether there was any considerable difference between the quantities taken by day and by night, and a station was made to study the vertical distribution of the plankton in the daytime. Towards the end of the twelve months the vertical distribution observations were further supplemented by similar stations taken by day and by night.

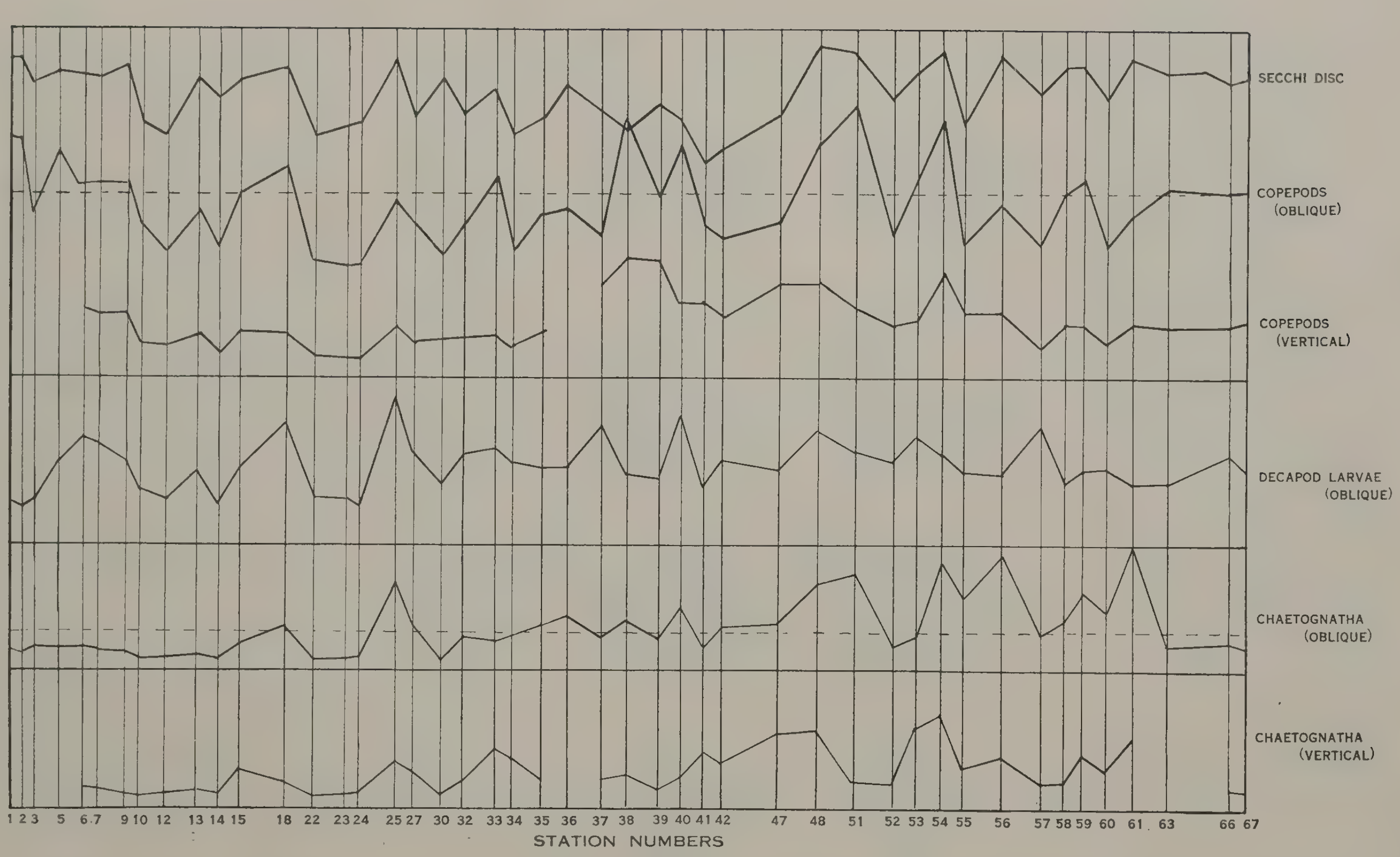
The vertical distribution was in general much like that in waters of similar depth in the English Channel off Plymouth, the majority of the plankton animals being well above the bottom, in the upper water layers, during daylight. The vertical distribution of all plankton animals and of copepods is shown diagrammatically in Text-fig. 3, and is very similar to that in the waters of the English Channel (Russell, 1925). On 22nd October, 1928, at Station 21, oblique hauls were made at night; the following figures for total animals were obtained: stramin, 9241; coarse silk, 47,526; fine silk, 9843. The corresponding figures for the daylight Stations 18 and 22 (15th October, 1928, and 23rd October, 1928) were: stramin, 5920 and 5165; coarse silk, 127,480 and 18,889; fine silk, 72,758 and 4102. It is usual to find that night catches are larger than similar daylight catches owing to the tendency for all animals to move towards the surface layers, and the differences between Stations 21 and 22 are no more than would be expected in northern latitudes. Except for the stramin net, the night catches do not approach the figures obtained in daylight in the previous week at Station 18. It would seem, therefore, that we were justified in making our collections by daylight, and that results as reliable as those obtained by similar methods in our own latitudes could be expected.

It is, however, necessary to make a closer comparison between the abundance of the animals and the transparency of the water, which has been shown to have a direct connexion with the wind (Orr, Vol. II, No. 3, p. 46). If this be done, rather striking features come out. At the top of Text-fig. 4 is given the curve joining the depths at which the Secchi disc disappeared at the weekly station three miles east of Low Isles throughout the period of the expedition. Immediately beneath this is given the curve for total copepods taken in oblique hauls of the coarse silk net at the same station. The latter curve follows very closely that for the transparency of the water, the peaks occurring when the water was least transparent and the troughs when the water was clearest. Immediately beneath these two curves is given that for the total copepods taken in the vertical hauls of the coarse silk net. This curve also follows that for the transparency of the water. The depth at the station was about 32 metres, and the vertical net was hauled from a depth with 28 metres of wire out, the length of the silk being another 2 metres. On windy days, with the stray due to drifting of the boat, the net would never quite reach 28 metres, so that there would always be some 4 metres or more near the bottom which were not fished through. From the agreement between these curves we must conclude that on the clearest days many of the copepods had moved into the lowest unsampled water layers. It is a remarkable fact that the day-to-day differences in the number of copepods shown in the curves would appear to be explainable to a very large extent by variations in the transparency of the water. This is a point that must be borne in mind when considering the seasonal changes in the abundance of the various plankton animals.



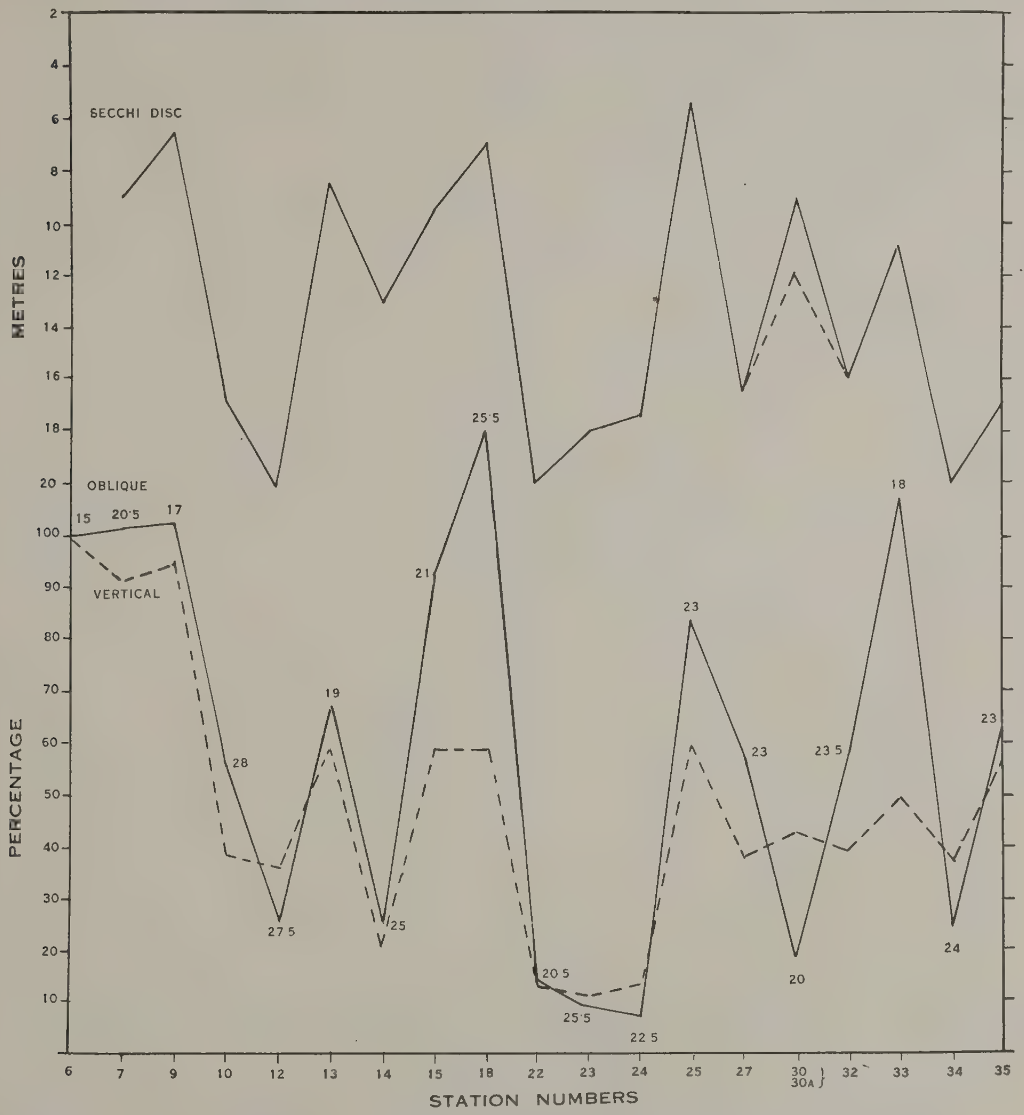
Text-fig. 3.—The vertical distribution of all animals and of all copepods in the daylight and at night at the position three miles east of Low Isles in the Barrier Reef lagoon. The white spots indicate the average depths at which the hauls were made. Coarse silk townet. S.D., Secchi disc reading.

In the previous report (Vol. II, No. 2, pp. 20–23) it was shown that on the average the proportion of the oblique haul catches to those of the vertical hauls was greater on days when the water was more turbid than on days when it was clearest, showing that



TEXT-FIG. 4.—Curves illustrating the relation between the transparency of the water, as shown by Secchi disc measurements, and the abundance of certain animals in oblique and vertical hauls with the coarse silk net at the position three miles east of Low Isles in the Barrier Reef lagoon.

animals had moved on clear days into layers only sampled by the vertical hauls. To compare the differences between the oblique and vertical hauls with the transparency of the water, the curves for these hauls have been drawn to the same scale in Text-fig. 5, in which the catches of copepods for both hauls are given as percentages of those at Station 6 (17th August, 1928) (the first at which both vertical and oblique hauls were taken),



TEXT-FIG. 5.—Curves illustrating the relation between the transparency of the water, as shown by Secchi disc measurements, and the abundance of copepods in oblique and vertical hauls with the coarse silk net at the position three miles east of Low Isles in the Barrier Reef lagoon. Oblique hauls ———; vertical hauls - - - - - - -. In each case the catch at Station 6 has been taken as the standard, the catches at the other stations being expressed as percentages of the catches at Station 6. The small figures on the curves are the maximum depths in metres to which the oblique hauls fished. The vertical hauls were from 28 metres.

and the curve of the transparency of the water is given above. Both curves agreed comparatively closely with that for the transparency; but on some days when the water was least transparent (high peaks on the transparency curve) the oblique haul catches were relatively much greater than those of the vertical hauls, *e.g.* Stations 15, 18, 25 and 33. This probably means that on those days the copepods were comparatively high in the water, and the oblique haul fished through the most populated zone for a proportionately longer time than did the vertical net, and is a confirmation of the results previously cited (Vol. II, No. 2, p. 20).

The correspondence in the results of the oblique and vertical hauls in relation to the transparency conditions is a further indication that the two methods have fished efficiently, and that they should show reliable results when the transparency factors are taken into consideration. What differences in abundance are we to regard as significant? If a horizontal line be drawn through the middle of the curve for copepods in the oblique hauls in Text-fig. 4, it will be seen that there are only one or two isolated peaks lying far above this line, and that there was really no season during which it could be said that the copepods were significantly more abundant save possibly from Stations 38 to 53. We must also examine the relations between the transparency and the abundance of other animal groups. In Text-fig. 4, immediately below the curve for copepods is given that for decapod larvae. Here again the curve shows a tendency to follow that for the transparency (but not as clearly as the copepods), and there is no very significant increase at any time of the year. Beneath this are given two curves for the abundance of Chaetognaths, the upper being that for the oblique hauls and the lower for the vertical hauls. Once more the curves show a tendency to agree with that for the transparency, but if, in this case, a horizontal line be drawn through the middle of the curve for the oblique hauls, it is seen at once that from Station 36 to Station 61 there is a significant increase in the number of peaks above the line, indicating a definite seasonal increase in abundance; this is confirmed by the curve for the vertical hauls.

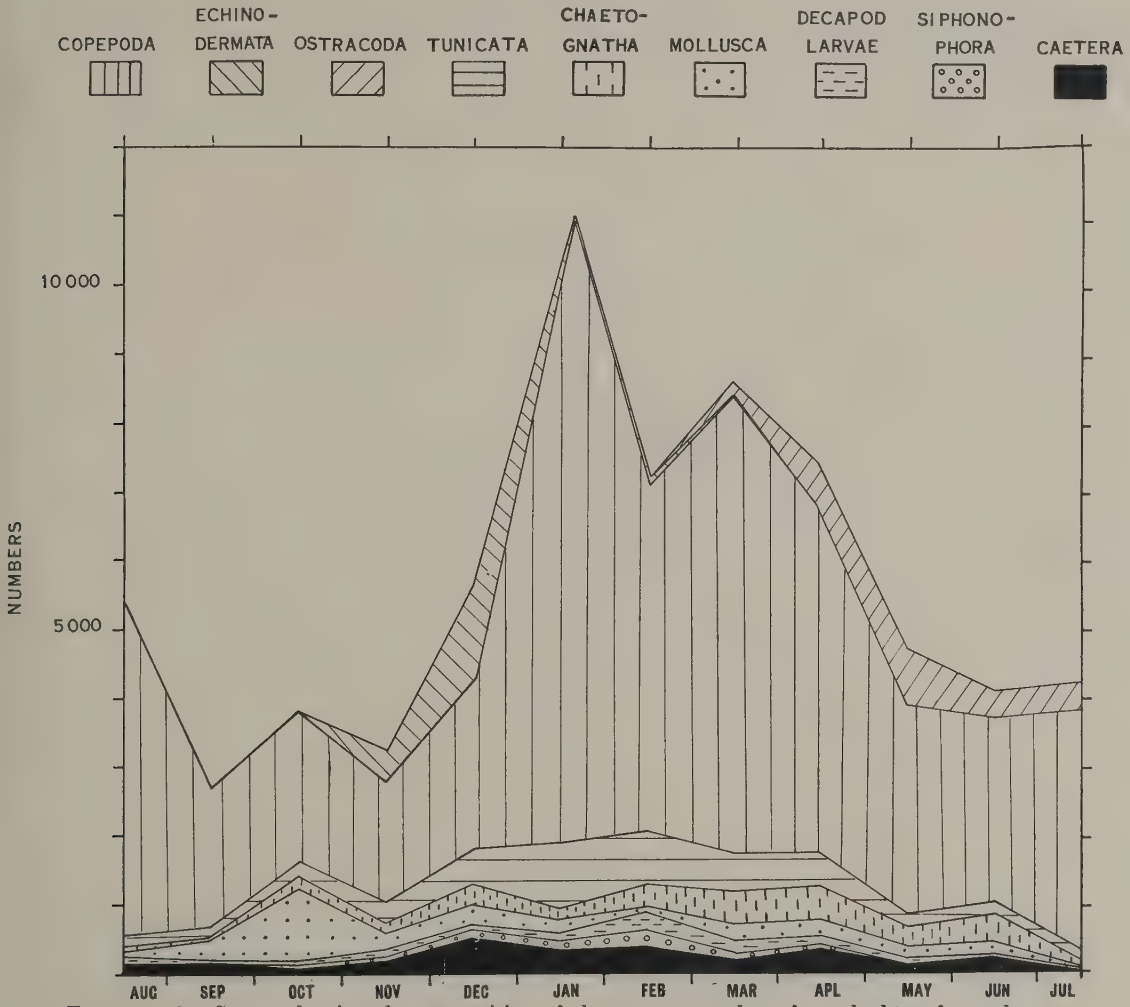
It is, therefore, very evident that when seasonal variations in number are not extremely marked, comparison with the transparency of the water must be made, as above, before they can be regarded as significant. The seasonal distribution will not be dealt with in detail in this report, but it seemed convenient to include the foregoing discussion when considering the reliability of our methods.

It may seem, perhaps, that the subject of method has been discussed at undue length, but it is thought that every effort should be made to show how reliable the results can be considered to be. We think that the very consistent results obtained by our collections should give faith in the reliability of the data to be discussed, and should prove a useful guide to those who may make similar collections in the future.

ON THE RELATIVE ABUNDANCE AND COMPOSITION OF THE ZOOPLANKTON.

The object of this report is to try and present some idea of the relative abundance and composition of the zooplankton in the Barrier Reef lagoon, in which our weekly collections were made at a position three miles east of Low Isles (depth 32 m.) (see Vol. II, No. 1, p. 3). It has already been shown that for the groups of the animal kingdom the data obtained by the vertical hauls are probably as reliable as any we can have. Our conclusions on the abundance of the smaller animals will therefore be chiefly based on the vertical net collections, supplemented by the results of the oblique hauls with the stramin net and, where necessary, by those with the coarse silk net.

In Text-fig. 6 is given the curve for the average abundance each month of all animals in the vertical hauls with the coarse silk net, showing the numerical proportions of the more important groups in the plankton for each month in the year; Text-fig. 7 shows the same for oblique hauls with the coarse silk net. The great preponderance of copepods is at once evident—a feature that is characteristic of the animal plankton all over the world. Taken over the whole year, the copepods formed 71·1% of the zooplankton in the vertical hauls; this estimate is supported by the results of the oblique hauls with the coarse silk net, in which the copepods formed 69·1%.* We can thus conclude that the copepods



Text-fig. 6.—Curves showing the composition of the average catches of zooplankton for each month in the vertical hauls with the coarse silk net at the position three miles east of Low Isles in the Barrier Reef lagoon, from August, 1928, to July, 1929.

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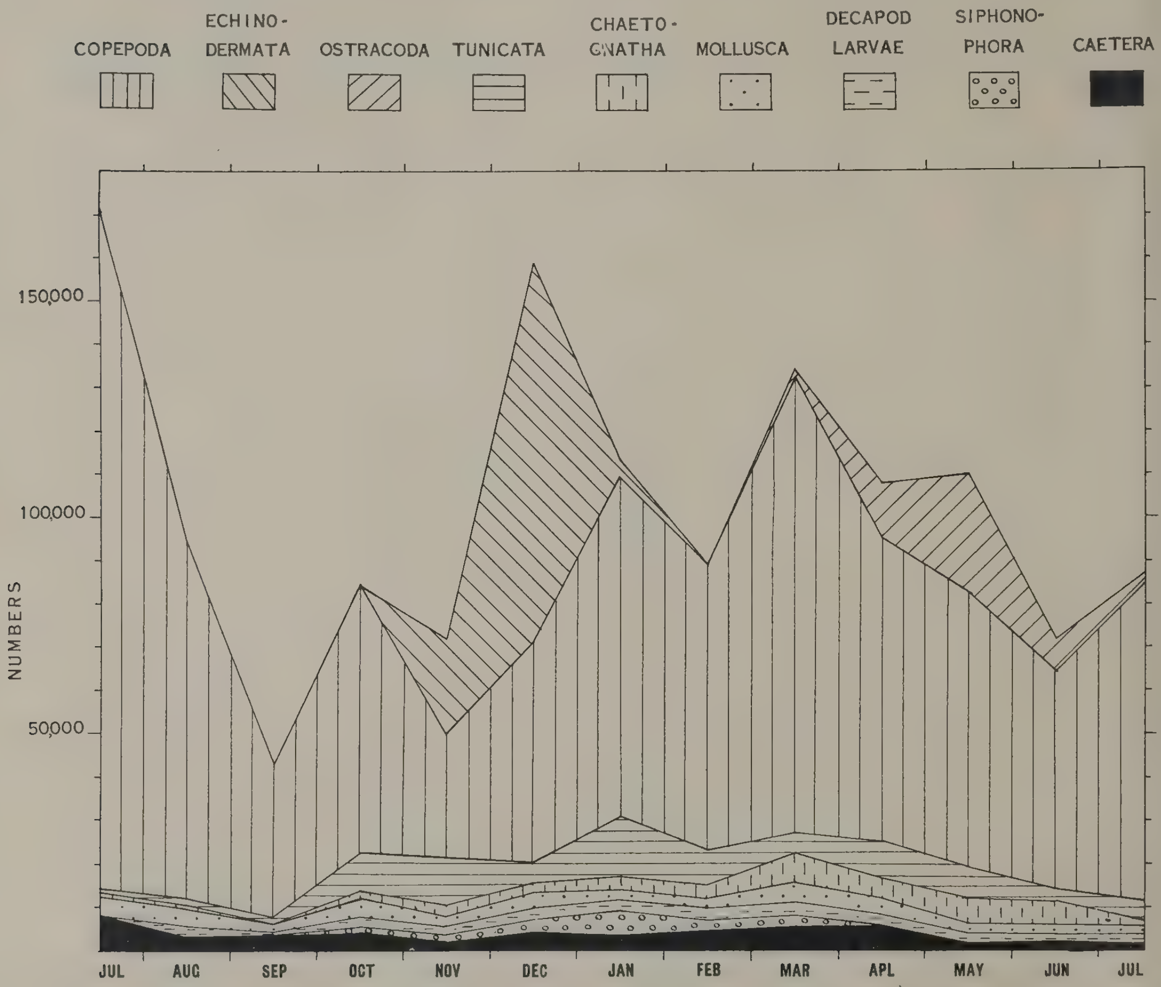
* In this report all yearly averages have been based on the summation of the average catches for each month.

formed approximately 70% of the average numbers of zooplankton for the year sampled by the coarse silk nets.

Other groups that assumed importance at times during the year are the tunicates



Text-fig. 7.—Curves showing the composition of the average catches of zooplankton for each month in the oblique hauls with the coarse silk net at the position three miles east of Low Isles, in the Barrier Reef lagoon, from July, 1928, to July, 1929. The very large catch of Echinoderm larvae at Station 32 has been included.

(Appendicularia and Thaliacea), chaetognaths, molluscs (Pteropoda and Heteropoda and mollusc larvae), echinoderm larvae (during November and December), ostracods (from March to July), decapod larvae and siphonophores. All other plankton animals were of comparative insignificance, and have been grouped in Text-fig. 6 and 7 under the title " Caetera ".

The average percentage representation of the more important groups in the plankton for the year, based on the average catches for each month, was as follows :

	Copepoda.	Tunicata.	Mollusca.	Chaetognatha.	Ostracoda.	Echinodermata.	Coelenterata.	Decapoda larvae.
Coarse silk :								
Vertical	71·1	7·1	4·7	4·2	3·9	3·1	2·1	2·0
Oblique	69·1	5·7	3·0	3·1	4·3	8·7	1·7	2·4
Stramin :								
Oblique*	14·6	52·1	2·2	8·6	..	..	9·5	9·0
Fine silk :								
Oblique	83·4†	2·7	7·9‡	1·4	1·3	1·2	0·6	0·3

* Excluding echinoderm larvae.
† Includes many nauplii.
‡ Includes one very large catch at Station 25.

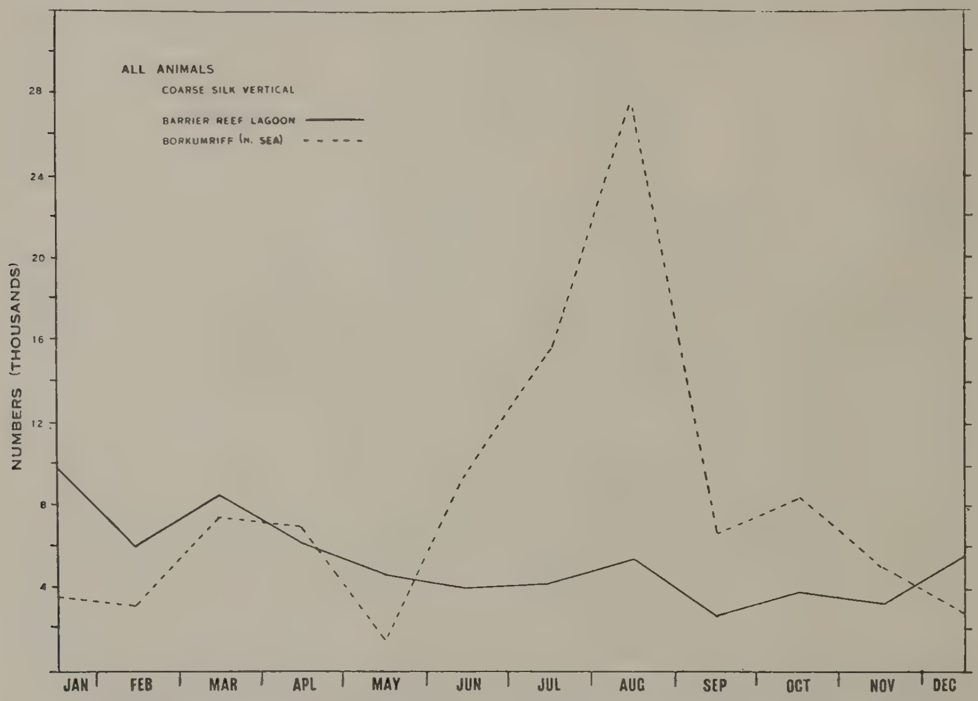
The only group showing considerable disagreement between vertical and oblique coarse silk net catches is the echinoderms, and this can be traced to the enormous shoal of larvae encountered at Station 32 (5th December, 1928).

Text-figs. 6 and 7 and Table II (p. 186) also show at a glance that the proportional composition of the plankton varied from time to time, sudden increases in abundance being exhibited, for instance, by echinoderm larvae, ostracods and salps. Increases in numbers over longer periods were shown by the Appendicularians from December to April, and the Chaetognaths from about February to June. These seasonal changes will be discussed in detail in a later report, when the specific composition of the different groups will be taken into consideration.

While it appears from the curves in Text-figs. 6 and 7 that there was definitely a difference in the abundance of the total zooplankton at different seasons of the year, this difference is not nearly so great as that found in northern waters. The lowest average catch in the coarse silk vertical hauls for any month was 2677 animals in September, and the highest was in January, when the average catch was 11,084. The proportion of these two figures was 1 to 4·1. Taking the copepods alone, the corresponding figures were 1728 in November and 9170 in January, or 1 to 5·3. Corresponding proportions for the coarse silk net oblique catches were 1 to 4 for all animals (although the maximum was obtained in July, 1928, in which month no vertical hauls were taken) and 1 to 5·4 for copepods (the maximum again being in July, 1928). In northern waters the seasonal variation in numbers is usually much greater. From Herdman and Scott (1913, p. 390) it is found that for the eight most important copepods the average catch in October is 27·4 times that in March. Bigelow (1926, p. 189) says that in Massachusetts Bay, in the Gulf of Maine, there may be 10 to 20 times as much animal life in the water in June as in March. Figures are given also on p. 177 for other localities in northern waters that bear this out, and in order to emphasize this we give in Text-fig. 8 curves of the average catch per month with the coarse silk vertical net in the Barrier Reef lagoon and from the Borkumriff lightship in the North Sea (see p. 177). Anyone who has experienced the great seasonal changes in abundance of animal plankton in northern latitudes would hesitate to say, on the results of one year's work, that the changes shown by our collections would be repeated from year to year. This is not to say that there were not very definite seasonal changes shown by certain groups, and by species in the groups, that may well be regarded as likely to repeat themselves annually; these will be dealt with in later reports on the different animal groups in the plankton.

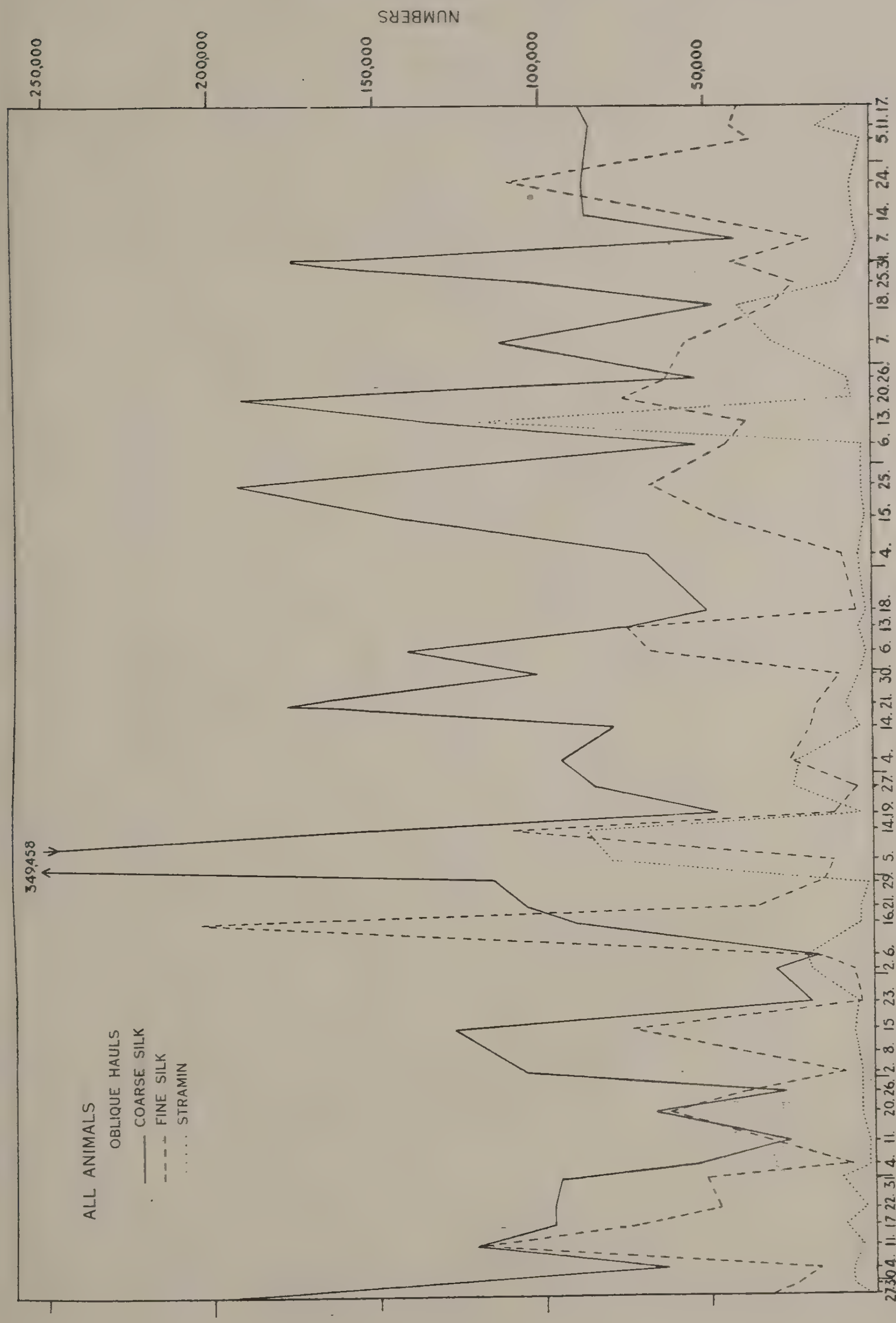
The great irregularity in the catches from week to week is shown in Text-fig. 9, in which curves are given for the total catches in the oblique hauls with the coarse and fine silk, and stramin nets, on each day of collecting.

We have so far only considered the abundance of the plankton as shown by the collections with the coarse silk net. In order to make the picture more complete, it is necessary to include also the larger plankton animals caught by the 1-metre stramin net. These were caught by oblique hauls, and must therefore be compared with the oblique hauls with the coarse silk net, the results of which we have shown to be reliable and in agreement with the vertical hauls.

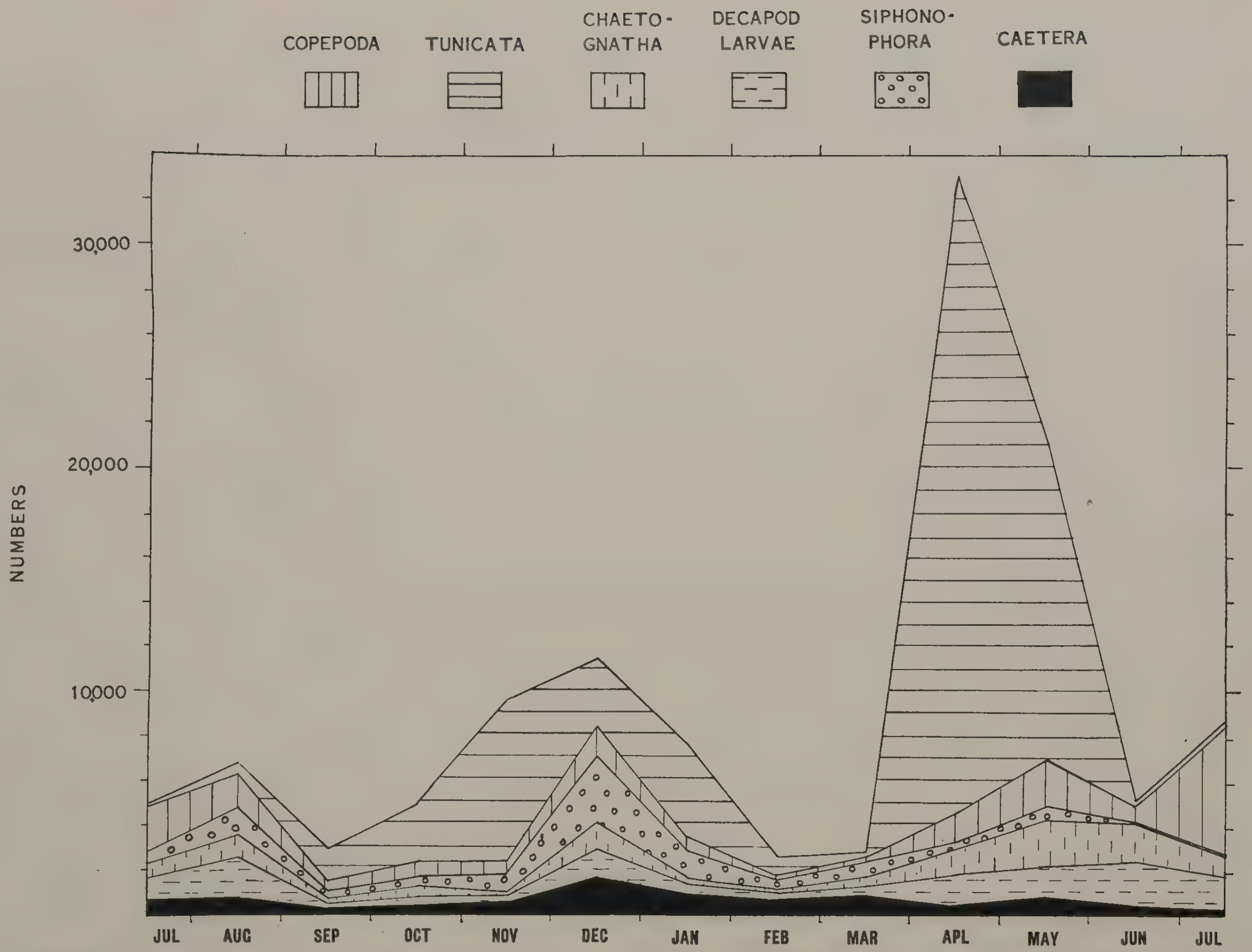


Text-fig. 8.—Curves showing the average catches of all animals for each month in the year in vertical hauls with the coarse silk net, taken at the position three miles east of Low Isles in the Barrier Reef lagoon (August, 1928, to July, 1929) and from the Borkumriff Lightship, in the North Sea, in 1910 (Lücke, 1912).

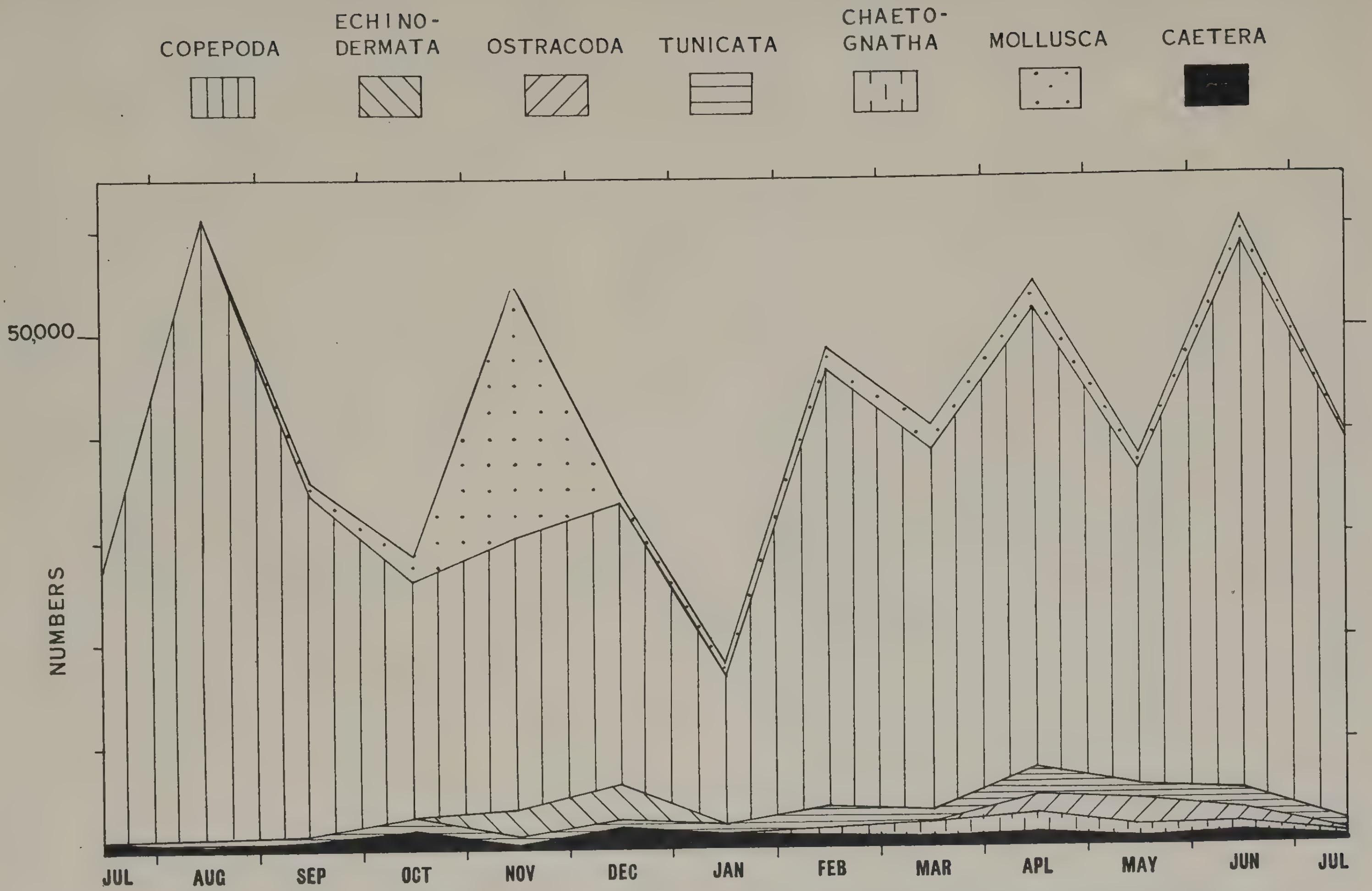
If we compare the average monthly figures (oblique hauls) for total animals in Table IX, we see a great difference between the coarse silk and stramin nets, the stramin net catches being very much lower in numbers. Furthermore, in the stramin-net catches the copepods did not play the predominating part that they did in the coarse silk net collections, forming only 14·6% of the whole as against 70% in the latter. The proportional composition and curve for average catches each month of all animals in the stramin net are given in Text-fig. 10, and the average percentage composition for



TEXT-FIG. 9.—Curves showing the actual catches of all animals in the oblique hauls with the coarse and fine silk and stramin nets at each station, taken at the position three miles east of Low Isles in the Barrier Reef lagoon, from July, 1928, to July, 1929.



TEXT-FIG. 10.—Curves showing the composition of the average catches of zooplankton for each month in the oblique hauls with the 1-metre stramin net at the position three miles east of Low Isles, in the Barrier Reef lagoon, from July, 1928, to July, 1929. Echinoderm larvae have been excluded as not being normal constituents of the catches with a stramin net; when they did occur it was probably due to clogging of the meshes by the great swarms indicated in the coarse silk net catches.



TEXT-FIG. 11.—Curves showing the composition of the average catches of zooplankton for each month in the oblique hauls with the fine silk townet, at the position three miles east of Low Isles, in the Barrier Reef lagoon, from July, 1928, to July, 1929.

the year of the more important groups is given in the table on p. 169, whence it can be seen that the tunicata (chiefly salps) were the most important group.

The average catch per month for the whole year in the stramin net was, for the copepods, 1361 as against 70,835 in the coarse silk net oblique hauls. The area of the mouth of the stramin net is four times as great as that for the coarse silk net; assuming, therefore, that in both nets all the water is filtered, approximately 340 copepods were caught by the stramin net compared with 70,835 by the coarse silk net in the same body of water. This indicates that the larger copepods were insignificant in numbers in comparison with the small copepods which can pass through the meshes of the stramin net but are retained by the coarse silk net. This is of importance for comparison with higher latitudes where the larger copepods may at times be very abundant. The meshes of the stramin net are large enough to allow copepods under 2–3 mm. in length to pass through head first and all copepods less than 2 mm. in length probably escape freely; the majority of the copepods in the coarse silk net were about 1 mm. long or less (see p. 180).

In Text-fig. 11 is given the curve for the average abundance each month of all animals in the oblique hauls with the fine silk net, drawn so as to show the numerical proportions of the more important groups in the plankton. This figure shows, like those for the coarse silk net catches, the great preponderance of copepods (which here include many nauplii) throughout the year. It is doubtful, however, whether we are justified in attaching much significance to the seasonal changes shown. We think that, owing to the possibilities of clogging, it was probably a mistake to use so fine a net for hauls of so long duration, and vertical hauls would probably have been more profitable. The results obtained serve, however, to show the composition of the zooplankton at any time given. Small protozoa and diatoms have not been counted from this net, as the results obtained by the centrifuge method are so much more reliable. The collections have proved of value to the specialists for searching for the smallest animals.

In general aspect the zooplankton catches were typical of those taken from warm waters. There was an appearance of transparency in the preserved material and an absence of the fatty residue which appears at times in plankton collections from northern latitudes owing to the great numbers of large copepods and other crustacea. Except for occasional swarms of salps, there was not one instance throughout the year of the very large swarms of larger animals, such as chaetognaths, medusae, copepods or euphausids, which in high latitudes give rise at times to plankton of a monotonous composition.

While it is true that our conclusions have been based on collections from one position only in the Barrier Reef lagoon, it seems likely that very similar conditions extend for a considerable distance north and south. We have evidence that this may be so to the northward at any rate, for in February and March, 1929, a few additional oblique collections were made, in the same way as at the weekly station, at Station 43 (26th February, 1929) off Cape Bedford, Station 44 (27th February, 1929) off Lizard Island, Station 46 (28th February, 1929) inside Cook's Passage, and Station 49 (17th March, 1929) inside Papuan Pass (for positions of these stations see Chart II, Vol. II, No. 1). The results of these collections are given in Table VI. It can be seen that the abundance and composition of the zooplankton at these stations was very similar to that at the position three miles east of Low Isles at about the same time. The total numbers of animals in the coarse silk catches were: Station 43, 109,401; Station 44, 106,803; Station 46, 54,375; and Station 49, 34,526, and are comparable with those for the stations near Low Isles, namely, Station 42, 49,539; Station 47, 68,266; and Station 48, 141,968.

COMPARISON OF TEMPORARY AND HOLOPLANKTONIC ANIMALS.

It is of interest in studying the composition of the plankton to note the proportion of holoplanktonic forms which spend their whole lives in the plankton to those which are only temporary constituents of the plankton, such as larval forms of benthonic and swimming animals.

We can regard the following as representative of temporary plankton animals: Medusae, coral planulae, polychaete larvae, cirripede larvae, decapod and euphausiid larvae, stomatopod larvae, gastropod and lamellibranch larvae, echinoderm larvae and post-larval fish. (Medusae may include certain Trachymedusae which are holoplanktonic.) It is calculated that in the coarse silk net vertical hauls over the whole year the temporary plankton formed on the average 10·8% of the whole plankton; the corresponding figures for the coarse silk oblique hauls are 15·4% and for the stramin oblique hauls 13·4% (excluding echinoderm larvae, which are not normally caught, and were only taken on account of very dense swarms clogging the net). The temporary plankton can thus be said to form 10–15% of the whole plankton taken by the nets in question. The various groups were represented as follows:

Percentage Composition of the Temporary Zooplankton.

	Coarse silk.		Stramin.†	Fine.‡
	Vertical.	Oblique.*		
Medusae	9·2	3·6	12·3	7·5
Coral planulae	0·0	0·6	0·0	1·1
Polychaeta§	4·3	1·2	1·7	10·0
Cirripedia	1·7	1·0	0·0	1·3
Decapoda	19·6	20·8	74·8	5·8
Euphausiacea	1·4	11·4	1·4	3·4
Stomatopoda	0·3	0·3	4·0	0·1
Gastropoda	17·8	11·0	3·2	18·3
Lamellibranchia	15·1	11·9	0·0	30·0
Echinodermata	27·6	37·3	..	22·0
Tornaria	0·9	0·2	0·0	0·1
Fish	1·2	1·4	2·6	0·7

* Excluding the very large catch of echinoderms at Station 32.
† Excluding echinoderms which are not normally caught in a stramin net.
‡ Excluding the very large catch of lamellibranchs at Station 25.
§ Includes a few Tomopterids and Alciopids.

It is evident that the most important constituents of the smaller plankton were gastropod and lamellibranch larvae, echinoderm larvae (restricted to a very short period of time), and decapod and euphausiid larvae. Of the two last the decapod larvae were usually the more important, although the euphausiid larvae were at times abundant. Among the larger plankton animals, as shown by the stramin net catches, the decapod larvae were easily the most abundant representatives of the temporary plankton, and the medusae (amongst which Trachymedusae were probably rather abundant) came next with a very much lower percentage.

The rarity of coral planulae in the catches was striking, and will be discussed in the report on the different groups. In contrast with northern waters there seem to have been rather few cirripede larvae. Owing to the great abundance of molluscs on the reefs, it was expected that the numbers of their larvae in the plankton would be high.

III. A COMPARISON OF THE ABUNDANCE OF ZOOPLANKTON IN THE BARRIER REEF LAGOON WITH THAT OF SOME REGIONS IN NORTHERN EUROPEAN WATERS.

By F. S. Russell, D.S.C., B.A.

The ultimate aim of plankton research is to obtain data that may be used in an estimate of the productivity of the sea, and to this end collections must be strictly quantitative. It was clearly not possible, in the time at our disposal, to emulate the exact work of Hensen and Lohmann, but we have, nevertheless, data which should supply us with information of interest. At this stage we do not know what factor to apply for the filtration and other errors of our net, so that we are not able to determine the number of animals per unit volume of water. It is hoped, however, that it may be found possible to calibrate the net (Harvey, 1934) so that later we shall be able to make comparisons between the actual abundance of the centrifuge plankton and of the zooplankton.

In the plankton programme carried out by the International Council for the Exploration of the Sea in northern European waters in 1910 and 1911, collections were made once a fortnight, or more often, from a number of chosen lightships. At each position vertical hauls were made with an Apstein net of No. 20 silk, and a Nansen net of silk No. 3 and diameter at the mouth of 50 cm. This Nansen net was of exactly the same dimensions and mesh as the coarse silk net used in our investigations, and with which we likewise took vertical hauls at almost every station. It will therefore be of interest to make a direct comparison between our results and those of the International Council. In the ' Bulletin Planktonique ' a number of tables are published recording the results of these systematic observations, and for some of the localities the actual numbers of different animals in the collections are recorded. We have summarized the results of some of the collections from five different localities -Anholt Knob in the Cattegat, Smith's Knoll and Borkumriff in the North Sea, and Varne and Sevenstones in the English Channel. In Table I are given the average monthly catches of all animals and of copepods alone. These results have been summarized below by calculating the average catch per year based on the average catches for each month.

TABLE I.—*Average Numbers in Collections Made by Vertical Hauls with Coarse Silk Net (Diameter 50 cm., Silk No.* 3).

TOTAL ANIMALS.

Light Ship.	Position.	Depth.	Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Anholt Knob	56° 46′ N., 11° 51·8′ E.	28 m	1910	684	3001	3796	1774	3911	2042	1950	1087	1235	3040*	3055	7272
	,, ,,	,,	1911†	1475	2116	1642	4072	2908	793	1618	940	1170	5483	2110	2585
Smith's Knoll‡	52° 52′ N., 2° 14′ E.	46 m.	1910	145	91	213	2101	2759	2132	1505	1260	472	1058	1788	45
Borkumriff	53° 45·5′ N., 6° 3·5′ E.	27 m.	1910	3638	3233	7535	7037	1528	9481	15,759	27,644	6743	8408	5037	2809
Varne	50° 56′ N., 1° 17′ E.	30 m.	1910	39	30	18	3935	580	1458	792	39	130	132	150	117
Sevenstones	50° 3′ N., 6° 4′ W.	72 m.	1911	171	179	193	1731	1114	8063	2034	2866	2159	3138	660	783
G.B.R. Lagoon	16° 23′ S., 145° 34′ E.	32 m.	1928–9	11,084	7199	8575	7362	4710	4075	4337	5501	2677	3808	3239	5639

COPEPODS.

Light Ship.	Position.	Depth.	Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Anholt Knob	..	..	1910	84	303	372	453	1570	1077	1520	280	125	215	95	222
	..	..	1911	225	279	245	1243	1045	163	861	265	503	118	98	120
Smith's Knoll	..	..	1910	16	30	153	1825	2399	995	733	710	209	397	1484	11
Borkumriff	..	..	1910	3567	3101	6090	5638	1087	4469	11,723	23,588	5673	6687	4566	2771
Varne	..	..	1910	32	19	9	3789	478	1018	637	23	34	77	31	68
Sevenstones	..	..	1911	128	116	170	1307	901	5416	897	2057	1709	2259	509	704
G.B.R. Lagoon	..	..	1928–9	9170	5047	6620	5040	3055	2690	3530	4888	1984	2231	1728	2464

* 15th October excluded. † Fish eggs excluded. ‡ Noctiluca excluded.

Average Catch for the Year.

Locality.	All animals.	Copepods.	Copepods %.
Anholt Knob	2737	526	19·2
	2243	430	19·2
Smith's Knoll	1131	747	66·2
Borkumriff	8238	6580	79·7
Varne	618	518	83·8
Sevenstones	1924	1348	70·0
G.B.R. Lagoon	5684	4037	71·0

We notice that except in the Anholt Knob collections, the copepods form between 66% and 83% of the total animals for the year. These net collections are similar in this respect to our collections from the Barrier Reef lagoon, where copepods formed 71% of the entire catch. In the Anholt Knob collections there were large numbers of *Sagitta* and *Cyphonautes* larvae of Polyzoa, and the plankton composition may perhaps be regarded as rather unusual.

In agreement with the observations given on p. 169, we also notice that the seasonal changes in the abundance of the plankton in these northern waters are very great compared with those in the Barrier Reef lagoon. If we divide the largest monthly average catch by the smallest we get the following figures:

	All animals.	Copepods.
Anholt Knob	10·6	18·7
	6·9	12·7
Smith's Knoll	61·3	218·1
Borkumriff	18·1	21·7
Varne	218·5	421·0
Sevenstones	47·2	46·7
G.B.R. Lagoon	4·1	5·3

If we compare the actual numbers in the catches in the northern waters with those from the Barrier Reef lagoon, we find that on the average for the year those of the Barrier Reef are easily the largest, except for the Borkumriff collections, which are only slightly larger. It was customary in the International Council Investigations in northern waters to make vertical hauls with the Apstein net as well as with the coarse silk net, and at many Barrier Reef stations an additional set of vertical hauls was made with an Apstein net of fine silk (200 meshes to the inch). These collections were worked out by Miss S. M. Marshall, and I am very grateful to her for these data. It has been mentioned above that the plankton from the Borkumriff Light Vessel was slightly richer than that from the Barrier Reef lagoon, and since the collections from this vessel have been treated in detail by Lücke (1912), it is interesting to compare our Apstein net results with his. It was found by Miss Marshall that the average catch for the year of copepods and copepodids in the Apstein net was 1492. Lücke (1912, p. 113) gives a table showing the abundance of the four most frequent copepods under 1 square metre of surface, which averaged 211,946 individuals for the year. To arrive at this figure he multiplied his catches by 80. The average number of these copepods in his actual catches must therefore have been 2649. This figure is 1·8 times that for the copepods in the Apstein net catches in the Barrier Reef lagoon—a proportion not far different from that of 1 to 1·6 shown by the catches in the two regions with the coarse silk net. These Apstein net catches thus tend to confirm the conclusion from our coarse net results that the Barrier Reef zooplankton is as rich numerically when averaged over the year as that of those northern regions compared. It has been found possible to test this result in yet another way, and it is so important in the consideration of the biology of this coral reef region that any comparison that we can make is of value.

Since returning to England I have had the opportunity of making a number of hauls in the English Channel off Plymouth with a coarse silk net of the same type as that used for our collections. Horizontal hauls of half an hour's duration were made at different depths to study the vertical distribution of the plankton in relation to light intensity (Russell, 1934). In each series of collections five or six nets were used, each fishing at a different depth ; by adding together all the catches at the different depths in one series and dividing by the number of nets used, we arrive at a figure that must be approximately equivalent to the catch of an oblique haul of half an hour's duration. The numbers so obtained were as follows :

English Channel, Two Miles East of Eddystone Lighthouse, 1931. *Calculated Oblique Hauls.*

	All animals.	Copepods.
21st July, two series	147,659	92,393
	251,939	103,983
22nd ,,	109,447	81,149
29th ,,	164,697	58,561
5th August	197,463	65,652
12th ,, two series	262,924	130,819
	601,340	194,768

This gives an average of 247,924 for all animals and 103,903 for copepods, compared with the average catches for the whole year in the Barrier Reef lagoon in the coarse silk net oblique hauls of 102,565 for all animals and 70,835 for copepods. The results show that in the hauls off Plymouth there were over twice as many animals as the average catch in the Barrier Reef lagoon and about one and a half times the number of copepods. (The high numbers of all animals compared with copepods in the Plymouth catches were due to the presence of enormous shoals of *Limacina.*) The Plymouth collections were made in July and August, at which time the plankton animals are many times more abundant than in the winter, so that when averaged over the whole year the Plymouth zooplankton would certainly not be numerically richer than that of the Barrier Reef lagoon.

It is also necessary to consider the volume of the plankton. It was very difficult to obtain a true idea of the volume, when settled, of the Barrier Reef plankton owing to the presence of numerous gelatinous appendicularian houses which prevented the plankton from settling into a compact mass. It is, however, interesting to compare volumes with the Plymouth plankton. At Stations 66 (11th July, 1929) and 67 (17th July, 1929) the volumes of the coarse silk oblique haul catches were 72 and 67 c.c. respectively, the total numbers of all animals and of copepods being at Station 66, 85,086 and 72,400, and at

Station 67, 88,169 and 74,200. Measurements of the volume of the plankton collected at three of the stations in the lagoon channel for the study of vertical distribution (Station 62, 15th June, 1929; Station 65, 10th July, 1929; and Station 68, 18th July, 1929) were also made. It was found that the average volume of the catches from the 18 ten-minute hauls at different depths was 51 c.c., the average number of all animals being 50,008 and for copepods 36,318. A similar calculation for the Plymouth hauls mentioned above gives an average volume per ten-minute haul of 42 c.c., and averages for all animals of 82,641, and for copepods of 34,634. Thus, although containing more animals, the Plymouth plankton had a slightly smaller volume than the Barrier Reef lagoon plankton. This must be accounted for by the very large numbers of *Limacina* in the Plymouth catches, which sink quickly down to form a very compact mass. Indeed, one had the impression that the majority of the animals in the Plymouth catches were more solid than those of the Barrier Reef, which, owing to their lightness and the presence of gelatinous appendicularian houses, did not settle so compactly. It was quite evident that the copepods from the Barrier Reef collections were, on the whole, smaller than those from Plymouth, and a random sample of 100 copepods was taken from one of the Barrier Reef lagoon collections (Station 42, 18th February, 1929, coarse silk vertical), and measured, with the following results:

Total body-length in millimetres.																		
·4.	·5.	·6.	·7.	·8.	·9.	1·0.	1·1.	1·2.	1·3.	1·4.	1·5.	1·6.	1·7.	1·8.	1·9.	2·0.	2·1.	2·2.
1	1	8	18	25	11	8	3	9	5	3	1	3	1	..	..	2	..	1

These measurements show that 64% of the copepods were less than 1 mm. in length and 92% less than 1·5 mm.

Now in the Plymouth coarse silk net plankton, and in that from the other northern localities mentioned, the dominant copepods are *Pseudocalanus*, *Temora*, *Centropages*, *Acartia* and *Calanus* (*Oithona* mostly pass through the meshes of the net). All of these are over 1 mm. in length, and most of them 1·5 mm. and more. The preponderance of very small copepods on the Barrier Reef lagoon plankton is thus quite evident, and the majority are, in fact, probably just about the minimum size that would be retained in any quantity by the coarse silk meshes. Farran (1927, p. 135) gives the size of the mesh as approximately ·33 mm. by ·37 mm., "a size that would admit under pressure most of the specimens of Stage I and a good many of the Stage II" *Calanus*. He found that the average size of the Stage I *Calanus* retained by the coarse silk net was ·93 mm., varying between ·90 and 1·0 mm., and that the diameter of this stage with the appendages pressed close to the body was about ·25 mm. For Stage II the average length of those retained was 1·28 mm., varying between 1·13 and 1·33, and the diameter ·3–·4 mm.

This raises the possibility that there may have been an even greater number of copepods than indicated by the coarse silk net if a large number have slipped through the meshes, and that our general picture of abundance may be misleading. A confirmation of the general picture has, however, been given above by the results of the Apstein net collection, which is of so fine a mesh as to allow no copepods to escape.

Before drawing final conclusions as to the abundance of the Barrier Reef lagoon plankton, it is necessary to make some comparison of the quantity of large plankton animals in the different areas. For this purpose we have, in the Barrier Reef collections, the oblique hauls with the metre stramin net. The meshes of this material allow all copepods below 2 mm. in length to escape freely, and this can be taken as being the lower limit of size of the animals retained. I have taken a large number of similar half-hour oblique hauls in the neighbourhood of Plymouth with a 2-metre ring-trawl made of stramin. The results of such collections over a period of one year have been published (Russell, 1933), and I have summarized some of the results for the period from February, 1930, to January, 1931, below. In order to compare them with those for the Barrier Reef lagoon, the figures for Plymouth have been divided by four, this being the number of times that the area of the mouth of the 2-metre ring-trawl is greater than that of the 1-metre stramin net.

	G.B.R. lagoon.		Plymouth.	
	All animals.*	Copepods.	All animals.	Copepods.
January	7605	733	641	38
February	2650	231	3419	230
March	2856	190	3306	71
April	33,089	1108	3384	1342
May	21,014	2028	34,729	29,646
June	5150	796	6086	1079
July†	6714	3839	17,447	1303
August	6773	1928	12,246	371
September	2970	477	4181	128
October	4901	675	968	42
November	9593	587	474	12
December	11,466	1269	508	50
Average	9565	1155	7282	2859

* Excluding echinoderm larvae. † 1928 and 1929 combined.

We thus see that there were, on the average, more large plankton animals in the Barrier Reef lagoon than off Plymouth, if the difference in the catching power of the two nets has been correctly estimated. The high numbers of all animals in the Barrier Reef collections in April and May have been caused by swarms of Salps. When we compare the number of large copepods in the two regions, it is found that there are twice as many off Plymouth as in the lagoon channel. But this has only been brought about by the very high numbers for May, which were produced by an enormous swarm of *Calanus finmarchicus* encountered on one day. In these stramin collections, as with the coarse silk collections, one had the impression that the plankton was not quite as solid in the Barrier Reef region as off Plymouth, lacking the large numbers of large crustacean larvae so prevalent at times in northern waters. It must not be forgotten, however, that this difference may be only apparent, since in the Barrier Reef region the larval stages are spread throughout the year, while in northern waters they tend to be concentrated in a limited period. Unfortunately, there are no similar data from any other regions with which we could make fair comparisons.

Consideration of these facts forces us to the conclusion that the Barrier Reef lagoon zooplankton must be of about the same abundance, on an average over the year, as that of the coastal and shallow waters of the southern North Sea and English Channel, where the plankton is possibly not as rich as in still more boreal waters. It seems, however, that the medium-sized copepods of the *Pseudocalanus*, *Temora* and *Centropages* type make up a much greater part of the plankton in northern waters, being replaced in the Barrier Reef region by copepods of a much smaller size. Also, during the year's observations on the Barrier Reef, we never met with such very large swarms of large copepods as are occasionally found in the northern waters we have mentioned.

In considering the year's production of plankton, there is also another factor that needs to be borne in mind. Owing to the high temperature of the water in the lagoon channel, it is possible that the rate of metabolism of both the plant and animal life is much higher than in cool northern waters. It is a point that has been raised many times before, and needs further study. Delsman, for instance, has shown that the rate of development of fish eggs in the warm waters of the Java Sea is enormously fast. He has shown that the larvae of many species hatch out within twenty-four hours after the fertilization of the eggs. To quote one example, the spawning of *Caranx kurra* takes place during the night, and the majority of the larvae are hatched between 11 a.m. and 1 p.m. the following morning (Delsman, 1926, p. 202). Anyone townetting in the afternoon would therefore never have found many eggs of this species in the plankton! In our northern waters the majority of fish take several days to hatch, and some even weeks. This possibly means that in the Java Sea metabolism is four or five times as fast as in our cool northern waters. Delsman states that the average temperature was certainly not less than 28° (1921, p. 98); this is slightly higher than the average temperature for the Barrier Reef lagoon, which ranged between 29·9° and 21·2° C. This is, however, still high enough to cause fairly rapid metabolism, and it might be expected that this would be two or three times as great as in the northern regions we have considered. It cannot possibly be conjectured what effect this will have on the annual production of zooplankton. It has been found, for instance, that in the northern waters mentioned there may be three or four generations in one species in a year. Are we to presume that in warm waters this number will be increased, or is there a limit to the number of generations that can be produced by a given species, and must a long resting period occur in one generation, as is the case with the winter generation in cool waters? This is a problem that must be answered by further research before we can obtain a true idea of the productivity of the area.

The apparent richness of the zooplankton in the Barrier Reef lagoon raises another point of great interest. It was shown by Lohmann (1908, p. 347) that while, during the winter, the proportions of producer plants to consuming animals were about equal, and might even give rise to a deficit of plants in Kiel Bay, in the spring and summer months there was apparently a considerable surplus of plant food. It seems possible that in some of these northern waters, such as Kiel Bay and the Clyde Sea Area, where there is a very great spring outburst of diatoms, a portion of the plant food may sink to the bottom before it can be eaten by the plankton animals, and thus become wasted as far as they are concerned, although, of course, becoming available then for bottom-feeding animals. That diatoms may thus pass out of the food supply of plankton animals is shown by Moore (1931, p. 348), who obtained evidence of an annual layering of diatoms on the sea floor in sheltered regions in the Clyde Sea Area. From the low figures obtained for the centrifuge plankton in the Barrier Reef lagoon (Marshall, Vol. II, No. 5), it is doubtful whether at any time of year there can be an excess of plant food available for the zooplankton. The hydrographical and weather conditions are such also that the diatoms are kept continuously in suspension, the population being enriched at times even by bottom-living species (Marshall, Vol. II, No. 5, p. 122). It would thus appear probable that throughout the year the animal plankton population is the maximum that the plant crop can support. A close study of this question might well repay us by affording an indication of the minimum crop of diatoms and other micro-organisms necessary to support a given quantity of animal life.

It is possible, therefore, that, in relation to the microscopic organisms, the animal plankton is on the average throughout the year more abundant in the Barrier Reef lagoon than in the northern waters considered. In the animal plankton it has been shown that the copepods are by far the most numerous animals, and it is interesting to find that nearly forty years ago Krämer gave a similar indication. In 1897 (Krämer, 1897, pp. 133–134) he compared the numbers of copepods with the numbers of all organisms (including phytoplankton) taken in a fine silk net in New Zealand waters and in the waters round Samoa. He found that in New Zealand waters the copepods (excluding nauplii) formed, on the average, only 9·9% of the whole plankton, while in Samoan waters they formed 80·8% (including nauplii). Even allowing for the fact that the nauplii have been included in the Samoan results, the difference between the two regions is very marked.

If the deductions are correct, there is a comparatively rich supply of plankton animals available as food. It remains for us to attempt to decide whether this food supply is sufficient to support the wealth of life of the Reef, which consists so largely of corals shown by Yonge (Vol. I, No. 2) to be to a considerable extent zooplankton feeders. In order to do this we must first find to what extent the plankton is likely to be preyed upon by other organisms. In a plankton community we have the producers, comprising microscopic plants and certain protozoa, and the consumers, which are the plankton animals. In the plankton animal community we have animals which feed directly upon the producers, and predatory animals, which prey upon the other members of the plankton animal population. Through the researches of Lebour (1922 and 1923) on the feeding of plankton animals, it has been shown that these predatory animals are chiefly coelenterates, chaetognaths, some of the larger crustacean larvae and the young fishes. In our Barrier Reef collections we may regard the following animals as forming the bulk of the predatory plankton population: medusae, siphonophores, chaetognatha, stomatopod larvae, fish larvae and fish eggs, which will develop quickly into the predatory larvae, and may therefore be regarded here as potential feeders. I give below the proportion of these predatory animals to the rest of the plankton animals, expressed as percentages of the average catch of all animals for each month in the coarse silk oblique collections. I also give similar figures for the vertical coarse silk net catches from Borkumriff in the North Sea, mentioned above.

We notice first that over the whole year the predatory animals are much more evenly distributed in proportion to the rest of the zooplankton in the Barrier Reef lagoon than they were at Borkumriff, where the majority were found in September, October and November. It also appears that they are slightly more predominant in the Barrier Reef lagoon than at Borkumriff. Nevertheless, this difference is not very great, and we can assume that at most there may be twice as many in the Barrier Reef waters (the corresponding average for the coarse silk vertical hauls is 6·6%).

In northern waters the animal plankton affords a food supply for enormous shoals of plankton-feeding pelagic fish, such as herring, mackerel and sprats. In Barrier Reef

Percentage of Predatory Plankton Animals.

	G.B.R. lagoon. Coarse silk oblique.	Borkumriff. Coarse silk vertical.
August	1·8	0·5
September	3·1	5·8
October	4·7	15·9
November	6·1	6·6
December	4·0	0·5
January	7·9	0·1
February	7·0	3·4
March	7·0	0·1
April	6·4	0·1
May	5·6	0·1
June	8·4	0·5
July	2·0 1·0	3·1
Average	5·0	3·1

waters large shoals of atherines and small sardine-like fish are at times met with, but it is possible (but by no means certain) that their numbers and feeding capacity are small compared with the great numbers of pelagic fishes occurring in northern waters. This would mean that a larger proportion of plankton animals would be available as a food supply for other zooplankton-feeding animals in the Barrier Reef waters than in northern waters. In northern shallow waters there is also a very abundant mass of bottom-living fish and invertebrate animals ultimately dependent on the total plankton production for their existence. The dredgings in the lagoon channel indicated that the non-coral-inhabited sea floor was poor in invertebrate life compared with northern latitudes (Vol. I, No. 1, p. 9). The corals rear themselves up into the waters from which they draw their food supply of zooplankton, and are thus hardly to be regarded as part of the normal bottom-fauna. In view of these considerations, the indications are (until more accurate data are available—see below) that the animal plankton may be sufficient to support the coral population and its abundant fauna, when we realize that the demands of a coral animal are probably small, since their flesh forms only a small part of their bulk. It has also been shown (Yonge, Vol. I, No. 2) that the majority of the corals feed at night, when the surface waters are rich in animal plankton (see Text-fig. 3). But apart from this, there is still an abundance of animal plankton life to be found over the reef flats at high tide, even in the daytime. The rough waters breaking on the edge of the reef will tend to bring up animals from deeper layers, which will be carried over the reef flats. Once a week we took townettings at high water over the sand flat at Low Isles, and the results of these collections are given in Tables VII and XI. The numbers caught are naturally much smaller* than in the weekly collections from the Barrier Reef lagoon owing to the smaller net used and the shorter period of towing, but these results will not be considered in detail here. It has already been mentioned that it is hoped to calibrate the coarse silk net (p. 176) so that it may be possible to give some estimate of the actual abundance of the zooplankton per unit volume of water. It will then be possible to compare the plankton of the Barrièr Reef lagoon with that over the reef flat, and to get an approximate figure of the amount of food available for the corals ; discussion on this matter must, however, await publication in another report. I do not feel justified in giving a final judgment on the question whether the zooplankton is sufficient to support the life of the coral reefs until this has been done. It must, however, be borne in mind that besides the purely planktonic animals, there are a number of bottom-living amphipods, mysids, cumaceans, ostracods and other forms of life which come up into the water at night and become available as food for corals. Examination of the night hauls in Tables VI and VIII, and of hauls with the bottom stramin net in the daytime, gives proof of this, and further mention will be made of it when the different groups are considered separately.

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* The average catch over the year was 5261 for all animals; if we multiply this by 8·25 to allow for the smaller area of the opening of the net, and for the shorter haul, we get 43,403 compared with the equivalent figure of 102,565 in the coarse silk net oblique catches.

It has been thought advisable not to give summaries at the end of this and succeeding reports. There is much information still to be gleaned from the data obtained, and the results of the examination of the different groups have yet to be published. When the final report is finished, it will be possible to review the plankton results as a whole, and the information obtained will then be summarized fully.

We should like to record our grateful thanks to Mrs. F. S. Russell and to Mrs. N. J. Berrill for the great assistance they have rendered in compiling and checking the tables.

TABLE II.—*Catches of Zooplankton in Half-hour Oblique Hauls with the Coarse Silk* (58 *Strands*

Station No.	Date.	Protozoa.	Medusae, etc.	Siphonophora.	Coral planulae.	Planaria.	Chaetognatha.	Polychaeta.	Cladocera.	Ostracoda.	Copepoda.	Cirripedia nauplii.	Mysidacea.	Amphipoda.	Euphausiacea larvae.	Euphausiacea adults.	Decapoda larvae.
1	27.vii.28	42	61	893	..	..	1198	1	..	600	188,742	..	8	185	1000	1	403
2	30.vii.28	8	30	199	..	..	828	1	..	1400	124,866	..	..	190	11,411	3	175
3	4.viii.28	2	5	376	..	..	1344	1	..	200	54,330	..	11	194	434	5	522
5	11.viii.28	..	131	270	..	..	1220	..	..	200	109,730	..	3	1380	..	2	2383
6	17.viii.28	1	129	456	..	..	1359	1	..	400	82,190	..	26	1027	1	..	3422
7	22.viii.28	2	83	411	..	..	1055	200	..	3200	83,260	..	1	222	1121	..	3154
9	31.viii.28	1	39	344	..	..	1014	1	..	1800	83,740	..	200	583	..	9	2242
10	4.ix.28	401	5	690	..	..	274	..	..	..	45,620	400	2	74	439	2	1017
12	11.ix.28	1	40	70	..	..	271	207	..	..	21,280	400	3	258	1297	..	537
13	20.ix.28	..	22	681	..	..	763	7	..	200	54,810	..	..	33	2354	1	1880
14	26.ix.28	800	20	222	..	..	179	1	..	..	20,763	..	..	10	491	..	264
15	2.x.28	1	54	672	..	1	1815	32	..	..	76,154	200	1	78	2580	2	2032
18	15.x.28	1800	642	2580	..	..	3220	627	..	3973	98,065	..	..	178	285	..	4200
22	23.x.28	..	95	522	..	..	272	2	..	..	11,130	..	..	1	161	..	601
23	2.xi.28	..	514	394	..	..	264	206	..	201	7506	..	..	213	2040	3	516
24	6.xi.28	..	89	1530	..	1	480	56	..	..	6001	..	..	39	491	..	124
25	16.xi.28	801	234	2400	..	..	7497	10	..	40	68,300	..	..	211	220	..	5340
27	21.xi.28	..	140	3265	..	..	3220	177	..	80	46,900	..	..	6	349	..	2766
30a	29.xi.28	..	79	35	..	..	80	17	..	400	15,341	..	..	12	820	..	1256
32	5.xii.28	..	934	1656	..	2	2193	910	200	800	41,764	..	..	13	20	..	2581
33	14.xii.28	20	526	3697	3040	2	1976	216	10	3600	87,701	1200	..	53	..	..	2851
34	19.xii.28	200	524	3384	30	..	2380	224	600	200	20,200	..	..	3	..	..	2322
35	27.xii.28	200	1560	2142	4	..	3133	245	800	10	53,003	..	..	4	601	..	1989
36	4.i.29	200	230	3532	..	..	4206	13	200	200	60,392	..	..	653	1200	..	1999
37	14.i.29	..	1882	1500	..	..	2140	466	1400	400	33,490	..	..	571	200	..	4027
38	21.i.29	20	373	12,583	..	..	4000	13	400	2200	144,400	..	..	383	1	..	1676
39	30.i.29	..	442	1181	..	..	2200	10	800	3800	71,000	..	..	450	..	..	1517
40	6.ii.29	..	3	2410	..	..	5100	21	30	30	113,501	..	..	884	1200	..	4510
41	13.ii.29	..	130	3650	..	..	1200	239	2200	200	49,201	..	..	36	..	..	1192
42	18.ii.29	..	83	1450	..	..	3300	42	200	400	35,000	200	..	43	20	..	2422
47	4.iii.29	..	242	1420	..	..	3600	..	..	1400	44,200	400	..	112	..	..	1945
48	15.iii.29	..	22	1455	..	..	7400	11	..	1400	115,200	..	..	703	1600	..	3822
51	25.iii.29	..	962	4436	..	..	8200	411	..	1600	155,200	400	..	844	5000	..	2828
52	6.iv.29	..	1535	500	..	..	1400	439	..	2100	33,600	..	..	300	20	1	2291
53	13.iv.29	..	1590	870	..	..	2400	224	..	18,500	76,401	600	..	190	3620	1	3576
54	20.iv.29	..	425	268	..	..	9200	31	..	24,000	141,200	400	..	850	2600	..	2684
55	26.iv.29	..	1636	650	..	..	5800	64	..	4000	28,200	..	..	280	1600	..	1826
56	7.v.29	..	22	60	..	..	10,000	40	..	27,600	64,000	..	..	180	..	1	1669
57	18.v.29	..	81	80	..	..	2400	72	..	4000	25,200	..	3	280	..	1	3971
58	25.v.29	..	282	490	..	..	3800	24	..	11,000	76,000	200	460	710	..	3	1333
59	31.v.29	..	144	100	..	..	6200	81	..	67,200	86,600	..	30	1310	65	3	1812
60	7.vi.29	..	832	49	..	..	4400	240	..	4400	23,201	..	..	400	80	..	1908
61	14.vi.29	..	87	60	..	..	10,600	33	..	16,800	51,200	..	35	190	40	2	1220
63	24.vi.29	..	71	90	..	..	1400	19	..	1400	76,600	..	28	150	..	..	1262
66	11.vii.29	..	103	50	..	..	1800	12	..	1200	72,400	..	41	61	..	..	2596
67	17.vii.29	1	78	200	..	..	1200	2	..	2800	74,200	200	9	140	8	1	1792

the Inch) Townet at the Stations in the Barrier Reef Lagoon 3 *Miles East of Low Isles.*

Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Cephalopoda young.	Echinodermata larvae.	Polyzoa, *Cyphonautes.*	Appendicularia.	Thaliacea.	Tornaria larvae.	Pisces ova.	Pisces post-larvae.	*Incertae sedis.*	Total.	Appendicularia houses.	Station No.
65	113	1	83	*	*	..	..	..	440	1	..	..	42	..	193,874		1
5	..	1	101	1770	2260	..	..	..	1143	11	..	3	..	1	144,406		2
25	8	1	69	1080	1650	..	..	..	2669	10	..	4	6	..	62,946		3
68	85	78	43	1330	2440	..	..	..	1810	3	..	4	12	..	121,195		5
3	16	63	81	5120	1090	..	200	..	990	45	..	34	86	..	96,740	430	6
..	24	5	126	860	1490	1	200	..	1443	418	..	19	20	..	97,315	650	7
..	17	26	3	1440	3000	..	200	..	1	11	..	35	41	..	94,547		9
..	1	11	210	990	1960	1	..	..	1433	11	..	24	17	..	53,582	120	10
1	1	..	4	510	140	..	400	..	431	293	..	281	11	..	26,436	50	12
2	1	6	59	2350	60	..	400	..	848	924	..	613	95	..	66,109		13
20	..	1	13	370	150	..	..	..	2054	621	..	1048	56	..	27,083		14
2	1	21	63	2880	780	..	400	..	2201	14,583	..	530	309	..	105,392		15
1	36	6	1253	2440	970	..	800	..	5063	260	..	459	692	..	127,480		18
..	..	2	1093	1490	1440	2	..	..	1223	1813	..	7	35	..	18,889	150	22
3	..	15	952	1270	140	..	..	..	24	15,662	..	15	65	..	30,003	110	23
2	1	3	340	160	80	..	..	..	990	6454	..	16	40	36	16,929	2	24
72	..	..	2080	1030	280	..	70	..	..	162	..	660	421	..	89,828		25
..	..	4	2512	800	480	..	26,000	..	18,120	..	..	64	251	3	105,137	7600	27
18	..	12	830	1739	140	1	83,300	..	11,117	2	..	40	120	..	115,359	13,620	30a
..	..	14	3025	2150	380	..	288,412	..	3254	862	..	14	272	2	349,458		32
1	..	21	4237	910	670	..	38,800	..	1200	622	..	233	60	..	151,646		33
94	..	72	239	680	110	2	9400	..	4147	1565	200	205	284	11	47,076		34
322	..	225	471	800	200	..	11,400	..	5452	1371	10	13	52	..	84,007		35
1914	..	41	1470	560	390	..	10,800	..	2435	3434	..	..	19	20	93,908	2200	36
1100	10	243	925	70	110	..	1800	..	26,200	822	..	206	225	..	77,787	33,200	37
11	..	26	3084	350	460	..	1200	..	6000	968	..	1	273	1	178,424		38
900	..	32	733	485	960	..	1800	..	13,600	641	..	203	26	1	100,781	12,400	39
3300	3	5	774	1560	2290	2	1820	..	3600	70	..	1	318	12	141,444	5600	40
30	20	12	1011	170	170	1	410	..	14,800	85	..	212	251	3	75,223	6600	41
430	..	17	227	260	200	..	..	..	4550	255	..	204	236	..	49,539	1200	42
1621	..	11	638	501	660	..	..	..	11,200	233	..	..	83	..	68,266		47
1632	..	1	841	1580	4220	..	1650	..	400	11	..	1	17	2	141,968		48
1640	..	50	2203	970	2130	..	1600	..	1800	10	600	1	76	..	190,961		51
230	..	9	580	1040	810	..	..	..	8000	273	..	1	53	1	53,183		52
2990	..	34	1150	810	860	2	..	..	400	17,726	..	..	850	..	132,794		53
1110	..	28	1312	1800	2000	..	..	..	3064	47	..	..	27	1	191,047		54
1400	37	20	1450	1870	840	..	..	..	3200	451	..	1	130	..	53,455	3400	55
170	..	25	714	390	1030	..	..	..	2200	3527	..	1	22	..	111,652		56
70	40	40	90	420	370	..	..	..	600	10,514	..	..	30	..	48,262		57
40	70	20	521	590	780	..	..	..	6065	293	..	1	470	..	103,152		58
100	20	70	1180	1680	2140	12	400	1200	4900	41	..	..	140	..	175,428		59
420	20	30	539	910	990	1	..	..	2420	333	..	..	243	..	41,416		60
50	17	1	132	600	2250	..	10	600	2000	2	..	20	50	..	85,999		61
80	10	15	735	600	440	11	..	600	3410	..	..	..	13	..	86,925		63
40	130	40	4	350	2610	16	..	..	3600	3	..	2	28	..	85,086		66
30	40	11	30	150	1190	10	400	200	5431	23	..	4	18	..	88,169		67

* Not counted.

TABLE III.—*Catches of Zooplankton in Half-hour Oblique Hauls with the 1-Me*

Station No.	Date.	Protozoa.	Medusae, etc.	Siphonophora.	Nemertini.	Chaetognatha.	Polychaeta.	Ostracoda.	Copepoda.	Mysidacea.	Isopoda.	Amphipoda.	Euphausiacea larvae.	Euphausiacea adults.	Decapoda larvae.
1	27.vii.28	25	4	610	..	140	..	..	990	3	..	120	..	1	326
2	30.vii.28	35	17	409	..	1299	..	..	3431	2	1	41	30	2	1510
3	4.viii.28	4	15	1419	..	370	..	..	3150	..	..	68	20	19	342
5	11.viii.28	..	51	636	..	1047	..	..	700	4	..	135	..	2	1176
6	17.viii.28	11	124	2024	..	1879	..	..	2850	45	..	479	2	..	1311
7	22.viii.28	1	31	191	..	150	..	..	1840	1	..	61	60	..	468
9	31.viii.28	3	35	1749	..	1179	..	..	1100	6	..	138	18	..	5296
10	4.ix.28	..	5	366	..	349	..	..	465	8	..	61	..	21	323
12	11.ix.28	5	15	289	..	183	4	..	605	1	..	69	12	..	159
13	20.ix.28	..	42	456	..	209	9	..	384	1	..	3	45	..	291
14	26.ix.28	..	6	315	..	183	1	..	453	..	..	3	15	..	91
15	2.x.28	..	8	255	..	1010	7	..	1220	..	..	66	90	..	237
18	15.x.28	1	34	336	..	233	3	..	254	..	..	20	..	..	811
22	23.x.28	..	66	707	..	110	..	..	550	..	..	2	7	1	188
23	2.xi.28	..	59	795	1	179	..	..	589	..	..	35	1	2	67
24	6.xi.28	..	28	487	..	75	1	..	661	..	..	166	3	..	158
25	16.xi.28	..	111	2230	..	150	1	..	40	..	..	1	..	..	355
27	21.xi.28	6	101	491	..	317	6	..	830	1	..	52	37	..	298
30	28.xi.28	1	212	103	..	540	2	..	815	..	..	4	..	..	205
32	5.xii.28	..	1002	4380	..	2250	21	..	1500	..	..	71	62	..	665
33	14.xii.28	..	181	2890	..	1490	832	200	1929	..	..	35	..	..	1829
34	19.xii.28	1	253	2062	..	161	..	..	82	..	..	44	..	..	399
35	27.xii.28	..	345	2900	..	690	3	..	1565	..	..	49	..	..	1326
36	4.i.29	..	268	3110	..	270	40	..	1890	..	..	91	..	..	344
37	14.i.29	..	173	500	..	70	4	..	40	..	..	41	..	..	279
38	21.i.29	..	367	690	..	650	2	..	942	..	..	11	..	..	163
39	30.i.29	..	81	545	..	30	3	..	60	..	..	10	..	..	194
40	6.ii.29	..	182	330	..	230	..	..	162	..	..	10	..	..	217
41	13.ii.29	..	320	560	..	80	..	..	180	..	..	7	..	..	191
42	18.ii.29	..	185	430	..	60	1	..	350	..	..	1	..	..	334
47	4.iii.29	..	563	709	..	465	..	..	350	..	..	27	..	..	419
48	15.iii.29	..	76	740	..	370	..	..	78	..	..	5	..	..	81
51	25.iii.29	..	219	510	..	490	..	..	143	..	..	13	..	..	550
52	6.iv.29	..	81	540	..	370	10	..	211	..	..	20	..	..	245
53	13.iv.29	..	129	235	..	1650	3	..	2700	..	..	140	16	..	1449
54	20.iv.29	..	153	110	..	2000	1	..	950	..	..	40	..	..	1667
55	26.iv.29	..	74	320	..	750	..	..	570	..	..	80	..	..	1539
56	7.v.29	..	24	460	..	1200	2	..	400	..	..	30	..	..	695
57	18.v.29	..	500	810	..	4000	19	200	1210	3	..	200	..	6	2223
58	25.v.29	..	164	580	..	1700	15	..	5001	80	..	220	10	..	773
59	31.v.29	..	140	390	..	1400	11	..	1500	7	..	310	10	..	876
60	7.vi.29	17	70	30	..	1300	3	..	638	4	..	560	150	10	666
61	14.vi.29	..	32	120	..	2200	..	..	1200	6	..	50	16	..	1309
63	24.vi.29	..	40	160	..	1300	..	..	550	1	..	60	2	..	3528
64	5.vii.29	8	57	10	..	900	..	..	800	54	..	70	27	3	474
66	11.vii.29	..	53	20	..	1200	..	..	11,800	25	..	140	30	8	2639
67	17.vii.29	..	27	220	..	740	1	..	3800	36	..	50	50	3	1031

min Net at the Stations in the Barrier Reef Lagoon 3 Miles East of Low Isles.

Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Cephalopoda young.	Echinodermata larvae.	Appendicularia.	Thaliacea.	Pisces ova.	Pisces post-larvae.	*Incertae sedis.*	Total.	Appendicularia houses.	Station No.
83	130	7	30	..	..	..	10	1	..	6	..	2486		1
44	1	13	76	..	..	..	229	21	18	6	..	7185		2
32	8	10	34	..	..	..	1811	12	17	2	..	7333	2820	3
37	133	77	91	10	1	..	..	9	8	4	..	4121		5
17	35	59	79	32	..	..	128	106	40	76	..	9297	580	6
2	11	43	56	..	2	..	12	254	111	16	..	3210	90	7
1	25	75	39	1	..	..	..	89	26	22	..	9802		9
1	5	3	61	..	..	..	123	42	83	10	..	1926	240	10
11	1	1	30	..	..	..	119	829	135	7	..	2475	30	12
28	1	3	40	1	..	..	138	1763	183	14	..	3622	40	13
1	2	3	11	..	..	..	417	2222	107	42	..	3872	100	14
1	1	15	52	1	1	..	2	565	68	25	..	3642	130	15
11	6	11	169	..	..	..	268	3602	101	60	..	5920	61	18
..	..	2	176	..	..	..	685	2545	99	21	7	5165	290	22
..	..	1	35	..	..	..	172	16,547	14	13	..	18,510	30	23
..	..	2	158	2	..	..	1069	16,861	33	13	1	19,717		24
1	..	..	114	13	..	..	..	210	343	2	..	3571		25
1	12	58	178	53	..	..	1148	11	147	32	..	3779	6240	27
17	12	18	39	5	..	..	293	27	54	34	..	2370	6715	30
10	..	53	112	..	..	67,400	100	911	16	58	..	78,601		32
24	..	84	498	..	..	76,200	610	600	3	30	..	87,435		33
51	..	72	106	48	..	..	926	84	101	42	1	4433	1760	34
500	..	250	237	1400	..	5000	148	9336	21	136	..	23,906		35
232	..	14	190	2	1	6880	610	8490	9	43	..	22,484	3400	36
100	..	70	460	..	..	..	2400	61	10	17	..	4225	6200	37
30	..	70	1246	1	..	..	860	2593	1	40	1	7667		38
280	..	80	143	4	..	600	1400	48	19	23	1	3521	1200	39
90	..	60	114	2	1	..	320	202	7	35	1	1963	320	40
80	..	35	307	3	..	..	1770	27	10	23	..	3593		41
100	1	70	93	1	..	..	440	86	193	57	..	2402	490	42
149	..	41	121	12	1	..	500	68	36	51	..	3512		47
110	..	24	17	..	..	..	..	9	2	20	..	1532		48
70	..	160	418	2	..	..	1	11	13	26	..	2626		51
40	..	20	180	24	..	..	430	86	2	22	..	2281	450	52
85	..	25	557	19	..	..	15	110,579	1	25	..	117,628		53
210	..	17	250	10	..	..	208	77	5	20	..	5718		54
550	40	210	140	30	..	..	650	1705	11	60	..	6729	1250	55
130	..	20	330	..	..	..	..	26,372	1	10	..	29,674		56
200	60	100	146	..	..	..	..	29,513	4	71	..	39,265		57
160	60	100	350	22	..	..	66	227	10	30	..	9568		58
130	70	100	190	80	..	..	50	185	..	91	..	5540		59
70	14	40	130	12	..	..	350	163	3	26	..	4256		60
160	1	34	200	..	..	..	..	7	3	14	..	5352		61
150	..	25	11	..	3	..	..	3	2	9	..	5844		63
6	26	4	63	..	..	..	700	61	2	20	..	3285	1500	64
20	180	18	30	1	2	200	10	1	3	22	4	16,406		66
11	230	13	19	..	..	..	20	15	5	11	..	6282		67

TABLE IV.—*Catches of Zooplankton in Half-hour Oblique Hauls with the Fine*
Lagoon 3 Miles

Station No.	Date.	Protozoa.	Medusae, etc.	Siphonophora.	Coral planulae.	Planaria.	Chaetognatha.	Polychaeta.	Cladocera.	Ostracoda.	Copepoda.	Cirripedia nauplii.	Mysidacea.	Amphipoda.	Euphausiacea larvae.	Euphausiacea adults.	Decapoda larvae.
1	27.vii.28	11	10	59	..	..	219	1	..	..	30,460	..	1	19	..	..	15
2	30.vii.28	1	1	9	..	..	94	..	..	400	22,259	..	..	..	900	2	11
3	4.viii.28	..	12	16	..	..	75	..	..	..	16,570	...	1	3	21	1	66
5	11.viii.28	..	10	19	..	..	177	..	..	200	117,300	..	2	11	..	..	200
6	17.viii.28	..	40	20	..	..	151	2	..	..	69,870	..	11	42	..	1	114
7	22.viii.28	..	2	..	..	..	84	200	..	400	45,960	..	10	10	62	..	133
9	31.viii.28	..	..	20	..	..	46	..	..	100	50,255	..	..	10	..	..	132
10	4.ix.28	1	..	1	..	..	2	200	..	..	6107	..	1	..	2	..	6
13	20.ix.28	1000	7	7	..	..	471	632	..	..	57,387	..	..	5	323	..	52
14	26.ix.28	1	4	10	..	..	133	1	..	..	35,227	200	1	..	65	..	9
15	2.x.28	200	20	3	..	..	29	3	..	..	6625	..	..	2	115	..	24
18	15.x.28	400	732	259	..	..	812	221	..	300	61,450	..	..	3	1	..	1293
22	23.x.28	..	8	13	..	..	211	119	..	100	720	..	..	..	44	..	6
23	2.xi.28	..	49	13	..	..	30	100	..	..	3515	..	..	2	300	5	10
24	6.xi.28	200	438	323	..	..	121	133	..	..	9380	..	..	21	27	..	21
25	16.xi.28	..	3	12	..	..	23	200	..	..	79,061	..	..	..	..	..	52
27	21.xi.28	..	633	4	..	..	202	842	..	..	27,230	..	..	1	105	..	85
30a	29.xi.28	..	52	81	..	..	142	22	..	20	11,600	..	..	2	1	..	148
32	5.xii.28	..	294	80	..	40	83	223	..	40	7308	..	..	..	21	..	74
33	14.xii.28	..	431	515	1230	5	1248	1501	200	1106	90,223	..	..	1	..	..	372
34	19.xii.28	..	239	208	10	10	223	6	15	..	7950	..	..	..	..	..	29
35	27.xii.28	..	72	100	..	60	74	44	..	40	3741	..	..	..	..	..	5
36	4.i.29	5	219	105	..	..	376	926	..	200	19,159	..	..	2	100	..	40
37	14.i.29	..	125	212	..	..	605	109	..	100	14,820	..	..	3	..	..	161
38	21.i.29	..	4	236	..	..	100	322	..	200	14,000	..	..	6	..	..	45
39	30.i.29	..	275	12	..	..	25	2	..	..	8800	..	..	21	..	..	19
40	6.ii.29	..	210	406	..	..	720	795	..	..	59,060	..	..	25	..	..	39
41	13.ii.29	..	229	315	..	..	1064	684	..	..	64,800	900	..	..	..	..	126
42	18.ii.29	..	103	41	..	..	384	54	1	1	3320	40	..	..	..	..	27
47	4.iii.29	..	44	20	..	..	300	145	..	100	6820	..	..	21	..	..	145
48	15.iii.29	..	212	288	..	..	1840	121	..	180	38,120	..	..	26	..	..	158
51	25.iii.29	..	363	105	..	..	1480	305	..	200	59,900	..	..	11	..	..	427
52	6.iv.29	..	630	16	..	..	795	253	..	921	36,600	5	..	8	..	..	387
53	13.iv.29	..	1025	..	..	..	1855	115	..	931	29,500	..	..	23	200	1	32
54	20.iv.29	2	481	2	..	..	2460	109	..	3900	62,900	..	..	31	700	..	251
55	26.iv.29	..	455	1	..	..	2100	720	..	420	49,600	..	..	15	..	..	172
56	7.v.29	..	221	1	..	..	1600	313	..	4100	46,300	..	..	2	..	..	152
57	18.v.29	..	39	..	..	..	800	5	..	600	26,500	..	..	3	..	..	281
58	25.v.29	..	10	5	..	..	700	105	..	800	18,700	..	3	101	..	..	23
59	31.v.29	..	40	3	..	..	1500	506	..	4600	30,900	..	5	25	3	1	64
60	7.vi.29	..	317	2	..	1	380	100	..	400	12,400	..	..	108	5	4	21
61	14.vi.29	..	120	15	..	..	1600	618	..	2900	44,300	..	4	10	5	3	70
63	24.vi.29	..	23	4	..	..	600	11	..	400	102,600	..	3	18	..	..	93
64	5.vii.29	..	35	..	..	..	1100	..	..	800	32,000	..	3	4	..	4	253
66	11.vii.29	..	15	6	..	..	40	6	..	..	40,900	..	1	8	..	..	105
67	17.vii.29	..	14	4	..	..	60	3	..	500	38,800	..	..	9	..	1	46

Silk (200 Strands to the Inch) Townet at the Stations in the Barrier Reef
East of Low Isles.

Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Cephalopoda young.	Echinodermata larvae.	Polyzoa, *Cyphonautes.*	Appendicularia.	Thaliacea.	Tornaria larvae.	Amphioxus larvae.	Pisces ova.	Pisces post-larvae.	*Incertae sedis.*	Total.	Appendicularia houses.	Station No.
22	1	..	10	..	..	..	..	..	42	2	..	..	..	1	..	30,873		1
1	1	..	12	..	..	..	..	..	85	1	..	..	..	..	..	23,777		2
1	4	1	..	..	..	..	..	..	483	..	..	..	1	1	..	17,256	670	3
3	11	9	5	110	310	..	..	..	800	..	..	..	1	4	..	119,172		5
..	..	11	21	..	..	..	400	..	710	20	..	..	..	7	..	71,420		6
..	4	..	10	..	..	1	..	..	461	..	..	..	..	4	..	47,341		7
..	7	8	..	..	..	..	..	..	200	1	..	..	1	2	..	50,782		9
..	1	..	..	100	100	..	..	..	100	..	..	..	..	..	..	6621		10
13	..	..	4	1400	..	..	..	..	603	18	..	..	18	36	..	61,976		13
..	1	..	2	1290	820	..	..	..	841	213	..	..	7	4	..	38,829		14
..	..	..	23	350	895	..	..	..	..	121	..	..	403	..	..	8814		15
7	6	1	1241	870	1760	..	..	..	3170	8	..	..	1	223	..	72,758	40	18
..	..	..	709	915	890	..	5	..	350	8	..	..	1	3	..	4102		22
..	..	..	51	500	500	..	200	..	100	248	..	..	..	9	..	5632	30	23
..	..	1	2327	510	535	..	..	..	818	1046	..	..	2	10	8	15,921		24
1	..	..	211	70	114,000	..	9600	..	..	..	..	..	..	10	..	203,243		25
..	..	1	39	922	640	..	3000	..	800	..	..	..	1	22	..	34,527	510	27
..	..	1	216	456	464	..	920	..	1145	..	..	..	..	44	..	15,414	540	30a
..	..	1	180	75	349	1	3140	..	304	100	..	..	..	34	..	12,347		32
1	..	1	2175	450	475	..	8500	..	600	..	..	..	200	21	..	109,255		33
3	..	..	202	258	410	..	400	..	1787	50	..	5	..	1	..	11,806		34
10	..	..	21	51	206	..	500	..	302	21	..	..	..	1	..	5248		35
33	..	2	1141	100	1435	..	600	..	355	213	100	..	..	5	..	25,116	75	36
23	..	..	327	40	230	..	300	..	2100	..	..	..	..	13	..	19,168	1800	37
1	..	1	1531	85	120	..	..	..	300	2	..	..	..	11	..	16,964		38
58	1	..	106	85	235	..	..	..	363	..	..	..	..	1	..	10,003	55	39
50	..	5	413	600	3000	1	200	..	1020	6	..	..	..	8	..	66,558		40
3	..	1	1013	85	535	..	..	..	4300	16	..	..	..	35	..	74,107	5000	41
11	..	..	2	27	105	..	..	..	466	..	..	..	1	10	..	4593	420	42
21	..	..	41	30	114	..	60	..	1100	21	..	..	..	7	..	8989	340	47
104	..	..	843	780	3260	..	20	..	240	2	..	..	..	9	..	46,203		48
8	..	8	323	510	1035	..	500	..	1700	..	..	..	..	15	..	66,890		51
14	..	2	531	295	655	..	100	..	3000	15	..	..	1	25	..	44,253		52
118	..	..	1537	285	995	..	..	..	911	209	100	..	..	6	..	37,843		53
21	28	1	1943	800	900	..	..	..	700	..	..	..	..	6	..	75,215		54
35	4	1	765	675	635	..	..	..	5600	26	..	..	..	22	..	61,246	Many	55
17	..	..	676	245	810	..	..	..	900	517	..	..	..	5	..	55,859		56
4	2	3	3	240	260	..	..	..	200	661	..	105	300	8	..	30,014		57
4	6	1	420	300	800	..	..	..	1220	4	..	..	..	4	..	23,206		58
5	5	6	621	385	795	..	..	..	2411	..	..	..	..	10	..	41,885		59
2	1	..	113	1780	1525	..	..	..	803	1	..	..	..	..	..	17,963		60
10	2	6	275	2015	2185	..	..	100	1001	..	..	..	..	3	..	55,242		61
20	3	..	862	410	760	..	10	..	3600	..	..	..	..	18	..	109,435		63
..	6	..	6	160	235	..	..	..	1620	..	..	..	5	3	..	36,234		64
..	14	1	..	5	55	..	..	..	910	5	..	..	..	1	..	42,072		66
13	3	..	..	35	350	..	..	..	430	..	..	..	1	..	..	40,269		67

TABLE V.—*Catches of Zooplankton in Vertical Hauls with the Coarse Silk* (58 *Strands*

Station No.	Date.	Protozoa.	Medusae, etc.	Siphonophora.	Coral planulae.	Chaetognatha.	Polychaeta.	Cladocera.	Ostracoda.	Copepoda.	Cirripedia naupli.	Mysidacea.	Amphipoda.	Euphausiacea.	Decapoda larvae.
6	17.viii.28	..	18	43	..	104	..	..	20	5123	20	..	21	..	102
7	22.viii.28	..	5	27	..	96	..	..	180	4680	..	4	9	5	134
9	31.viii.28	1	3	17	..	50	..	..	100	4862	..	21	85	..	54
10	4.ix.28	..	..	2	..	9	..	..	40	1991	..	..	..	..	5
12	11.ix.28	20	12	1	..	20	20	..	20	1871	20	..	2	63	52
13	20.ix.28	60	1	32	..	75	22	..	..	3021	20	..	1	38	63
14	26.ix.28	40	..	21	..	41	..	..	..	1052	..	..	1	51	2
15	2.x.28	..	41	2	..	264	1	..	40	3028	..	..	1	71	84
18	15.x.28	..	63	128	..	169	1	..	80	2998	..	..	4	..	46
22	23.x.28	..	..	34	..	19	..	..	20	668	..	..	20	30	44
23	2.xi.28	..	33	28	..	58	2	..	..	580	..	..	..	1	5
24	6.xi.28	..	22	10	..	37	1	..	5	685	..	..	1	6	53
25	16.xi.28	..	26	79	..	305	60	..	..	3220	..	..	40	1	305
27	21.xi.28	1	4	63	..	269	11	..	40	1970	..	..	23	23	154
30	28.xi.28	..	68	55	..	29	89	..	50	2184	..	..	4	1	200
32	5.xii.28	..	111	54	..	138	51	..	80	2235	..	..	..	8	136
33	14.xii.28	..	27	253	180	457	41	40	140	2540	..	..	2	..	119
34	19.xii.28	..	333	17	..	377	212	100	..	1906	..	..	2	..	58
35	27.xii.28	..	186	187	1	189	106	40	..	3176	..	..	..	80	30
37*	14.i.29	..	123	36	..	170	3	..	..	8000	..	..	1	..	115
38	21.i.29	..	7	8	..	205	4	..	..	9810	..	..	..	..	66
39	30.i.29	..	21	313	..	97	5	..	100	9700	2	..	14	..	247
40	6.ii.29	..	3	106	..	190	123	..	..	5300	..	..	6	..	567
41	13.ii.29	..	47	342	..	440	66	1	40	5380	180	..	21	..	115
42	18.ii.29	..	123	224	..	330	42	20	40	4460	..	..	2	..	147
47	4.iii.29	..	87	60	..	600	46	..	60	7400	60	..	5	..	340
48	15.iii.29	..	70	7	..	640	21	..	160	7420	20	..	1	..	126
51	25.iii.29	..	4	181	..	160	40	..	220	5040	20	..	67	..	65
52	6.iv.29	..	284	70	..	120	31	..	160	3500	..	..	24	..	143
53	13.iv.29	..	288	49	..	640	13	..	960	3800	40	..	5	2	312
54	20.iv.29	..	27	63	..	780	..	..	860	8460	..	..	53	1	253
55	26.iv.29	..	101	22	..	280	24	20	320	4400	..	..	4	..	80
56	7.v.29	..	7	1	..	380	4	..	880	4440	20	..	31	..	73
57	18.v.29	..	4	4	..	133	..	..	60	1161	..	..	..	..	8
58	25.v.29	..	42	3	..	130	2	..	660	3321	..	1	34	..	260
59	31.v.29	..	13	7	..	400	..	..	1720	3300	..	2	69	..	46
60	7.vi.29	..	141	1	..	260	43	..	120	1880	..	..	26	1	79
61	14.vi.29	1	44	2	..	520	42	..	660	3500	..	..	8	1	41
66	11.vii.29	..	2	..	..	80	1	..	340	3140	..	6	5	1	173
67	17.vii.29	..	4	10	..	63	1	..	420	3920	..	..	6	..	26

* St. 37 also contained six brachiopod larvae not included in total.

to the Inch) Townet at the Stations in the Barrier Reef Lagoon 3 Miles East of Low Isles.

Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Cephalopoda young.	Echinodermata larvae.	Appendicularia.	Thaliacea.	Actinotrocha larvae.	Tornaria larvae.	Pisces ova.	Pisces post-larvae.	Total.	Appendicularia houses.	Station No.
3	2	3	5	120	..	..	..	125	..	..	..	..	9	5718	7	6
..	3	..	5	12	142	..	..	278	1	..	..	..	..	5581	31	7
..	5	..	2	..	..	..	..	1	1	..	..	3	..	5205		9
..	..	..	1	46	106	..	..	21	..	..	..	1	..	2222	1	10
..	..	..	1	40	20	..	..	240	2	..	..	26	..	2430	2	12
2	..	1	1	196	38	..	2	112	1	..	..	2	44	3732		13
..	..	1	9	516	192	..	..	257	38	..	..	106	1	2328		14
..	..	..	26	52	6	..	..	201	1	..	..	1	..	3819	40	15
..	..	1	291	351	539	..	..	174	86	1	..	21	4	4957		18
..	..	..	9	1380	260	..	..	90	69	..	..	3	1	2647	5	22
..	..	..	52	46	12	..	..	2	400	..	..	..	1	1220		23
..	..	1	47	210	60	..	..	77	401	..	..	1	..	1617	85	24
7	..	..	73	300	62	..	80	20	1	..	..	..	43	4622		25
..	3	..	49	82	29	..	120	351	..	..	..	2	25	3219	141	27
..	..	..	37	97	95	..	2120	395	20	..	..	62	6	5512	280	30
..	..	..	83	28	41	..	1620	227	26	..	..	..	20	4858		32
21	..	1	142	83	126	..	2460	40	..	20	..	20	4	6716		33
105	..	2	206	62	70	..	405	1111	53	..	..	..	5	5024		34
..	..	..	48	61	166	..	1020	544	130	..	1	..	2	5967		35
21	6	2	20	15	20	..	200	2100	21	..	..	..	..	10,853	2100	37*
16	..	1	8	20	40	..	..	155	34	..	..	..	1	10,375		38
91	..	1	403	45	45	1	..	600	21	..	200	5	111	12,022	1100	39
155	3	2	13	30	50	..	200	430	1	100	..	5	8	7292	600	40
7	..	..	83	24	67	..	20	1360	1	1	..	..	2	8197	720	41
24	..	21	10	10	19	..	21	587	27	..	..	2	1	6110		42
44	..	..	41	83	37	..	121	1480	133	..	1	..	21	10,619	420	47
2	..	..	103	49	377	..	40	20	..	20	..	..	..	9076		48
1	2	22	23	25	78	..	20	60	..	1	..	..	..	6029		51
3	..	1	68	112	111	..	20	900	..	..	..	..	3	5550		52
92	..	3	74	75	122	..	..	100	377	..	..	1	2	6955		53
41	..	1	118	17	62	..	1	320	..	40	..	..	3	11,100		54
23	4	..	101	59	93	..	40	350	6	..	..	..	2	5929		55
4	2	2	68	48	142	..	..	182	40	..	..	..	1	6325		56
..	..	..	3	9	15	..	..	81	26	..	..	..	1	1505		57
2	..	1	71	37	98	..	..	241	29	..	..	40	1	4973		58
11	..	3	62	81	158	..	20	160	51	..	..	..	6	6109		59
23	..	..	23	111	62	..	..	181	2	..	..	..	..	2953		60
..	3	..	52	37	95	..	..	200	..	..	..	..	1	5207		61
1	10	3	..	6	97	..	..	241	..	..	..	..	2	4108		66
..	5	1	..	5	8	..	..	105	..	..	..	..	1	4575		67

TABLE VI.—*Catches of Zooplankton with the Coarse Silk, 1-Metre Stramin, and Fine Silk Townets, and*

Station No.	Date.	Locality.	Protozoa.	Medusae, etc.	Siphonophora.	Planaria.	Nemertini.	Chaetognatha.	Polychaeta.	Cladocera.	Ostracoda.	Copepoda.	Cirripedia nauplii.	Mysidacea.	Cumacea.	Isopoda.	Amphipoda, Gammarid.	Amphipoda, Hyperiid.	Euphausiacea larvae.
COARSE SILK NET.																			
8	24.viii.28	I.T.O.	5	8	45	..	..	150	..	..	..	5405	..	..	..	..	..	36	145
11	6.ix.28	I.T.O.	2	1	64	..	..	318	..	..	..	26,450	..	..	..	..	..	20	1082
19 (i)	20.x.28	O.T.O.	35	34	87	13	..	862	16	..	..	2014	..	..	..	..	..	9	131
19 (ii)	20.x.28	O.T.O.	..	17	126	1	..	440	11	..	1	7759	..	..	..	..	..	5	19
20	20.x.28	O.T.O.	..	5	133	2	..	363	8	..	203	14,604	..	..	..	..	..	8	37
21	22.x.28	3 m. E. night	..	669	1980	1	1	3360	7	..	272	28,800	..	2	..	..	31	526	2015
26	19.xi.28	I.T.O.	..	61	1930	..	..	845	3	..	..	47,241	..	..	..	..	..	3	620
28	23.xi.28	O.T.O.	501	106	113	6	..	195	121	..	528	6699	..	17	..	..	..	6	..
43	26.ii.29	C.B.	..	49	1502	..	..	3400	287	200	1200	84,200	800	..	..	..	..	489	4000
44	27.ii.29	Li.I.	..	710	813	..	..	7600	53	200	800	77,000	2200	..	..	..	..	14	5200
45	28.ii.29	O.C.P.	..	4	43	..	..	800	244	..	636	13,202	600	..	..	..	..	11	450
46	28.ii.29	I.C.P.	..	272	20	..	..	2200	2	1600	400	31,600	1000	..	..	..	..	2	..
49	17.iii.29	I.P.P.	10	292	1282	..	..	800	25	..	200	21,800	..	..	..	..	..	210	620
50	18.iii.29	O.P.P.	1	101	..	..	..	520	117	..	201	7615	100	..	..	..	..	4	200
1-METRE STRAMIN NET.																			
8	24.viii.28	I.T.O.	10	8	166	..	..	258	..	..	..	380	..	..	..	..	..	23	68
11	6.ix.28	I.T.O.	11	5	49	..	..	160	..	..	..	41	..	..	..	..	..	32	92
19	20.x.28	O.T.O.	32	21	108	..	..	145	6	..	..	365	..	..	..	..	..	12	39
21	22.x.28	3 m. E. night	..	36	1013	..	..	386	2	..	62	2160	..	41	3	..	..	151	131
26	19.xi.28	I.T.O.	8	96	462	..	..	216	2	..	..	40	..	..	..	..	..	2	..
28	23.xi.28	O.T.O.	2	8	162	..	..	128	36	..	3	350	..	..	..	..	1	5	41
29	24.xi.28	O.T.O. B.S.N.	..	..	10	..	..	6	5	..	6	1774	..	96	32	2	29	12	10
31	2.xii.28	3 m. E. B.S.N.	..	53	830	..	..	121	..	..	2	20	..	..	..	..	2	17	..
43	26.ii.29	C.B.	..	77	342	..	..	205	2	..	..	210	..	..	..	..	..	2	..
44	27.ii.29	Li.I.	..	264	149	..	..	300	2	..	..	250	..	..	..	..	..	2	10
45	28.ii.29	O.C.P.	1	7	31	..	..	55	1	..	..	75	..	..	..	..	..	5	10
46	28.ii.29	I.C.P.	..	413	75	..	..	550	1	..	..	200	..	..	..	..	..	28	..
49	17.iii.29	I.P.P.	1	144	560	..	..	220	1	..	..	220	..	..	..	..	..	80	20
50 (i)	18.iii.29	O.P.P.	..	92	113	..	..	338	2	..	1	441	..	1	..	..	..	31	..
50 (ii)	18.iii.29	O.P.P.	3	87	76	..	..	240	..	..	..	152	..	..	..	..	..	8	..
FINE SILK NET.																			
8	24.viii.28	I.T.O.	500	2	3	..	..	22	500	..	..	17,955	200	..	..	..	..	1	18
11	6.ix.28	I.T.O.	301	..	8	..	..	44	500	..	..	28,110	100	..	..	..	..	..	136
21	22.x.28	3 m. E. night	..	10	6	..	..	235	51	..	211	5655	..	..	..	201	..	..	45
26	19.xi.28	I.T.O.	2	111	543	..	..	271	202	..	..	49,400	..	..	..	..	..	..	..
43	26.ii.29	C.B.	40	62	100	..	..	600	448	..	60	15,620	120	..	..	..	..	21	40
44	27.ii.29	Li.I.	..	24	40	1	..	163	284	..	20	4180	..	..	..	..	..	1	40
49	17.iii.29	I.P.P.	..	16	16	..	..	895	634	..	..	34,900	..	..	..	..	..	17	..
SMALL COARSE NET.																			
	Date.																		
	19.ix.28	L.I.A.	..	113	22	..	..	396	1	..	20	1417	..	..	..	..	..	..	..
	28.ix.28	L.I.A.*	..	668	162	..	..	117	3	..	..	18,331	..	1	..	2	..	..	1
	1.x.28	L.I.A. night	..	44	108	..	..	109	6	..	31	1560	..	13	330	48	113	..	1
	1.iii.29	T.I.L.	..	..	..	..	..	..	..	..	20	120	..	..	..	..	..	..	..
	23.v.29	L.I.F. night	..	20	..	..	..	440	20	..	1080	7380	..	11	3	..	212	..	..
	28.vi.29	L.I.A. night	..	1	..	..	..	600	2	..	238	5800	..	15	36	3	..	8	..

I.T.O., in Trinity Opening; O.T.O., outside Trinity Opening; Li.I., off Lizard Island; C.B., off Cape Bedford O.C.P., outside Cook's Passage; I.P.P., insi

* Coarse silk townet—10 minutes.

with the Small Medium Townet at Stations other than that 3 Miles East of Low Isles, and at Night.

Euphausiacea adults.	Decapoda larvae.	Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Cephalopoda young.	Echinodermata larvae.	Appendicularia.	Thaliacea.	Tornaria larvae.	Amphioxus larvae.	Pisces ova.	Pisces post-larvae.	*Incertae sedis.*	Total.	Appendicularia houses.	Station No.
COARSE SILK NET.																			
1	321	7	39	12	17	..	..	1	..	231	3	..	..	8	31	..	6465		8
11	1927	1	10	7	13	420	170	1	..	400	10	..	..	..	56	..	30,963		11
..	97	15	..	3	..	13	19	3	..	5	124	1	..	6	2	8	3497		19 (i)
..	7	..	..	..	2	205	270	..	..	400	28	..	..	..	..	18	9309		19 (ii)
1	12	1	..	..	..	9	145	..	100	300	..	..	..	1	1	1	15,934		20
..	3833	1	88	..	693	841	300	..	..	2850	2074	..	..	51	131	..	47,526	70	21
..	2968	..	..	44	362	2440	1280	..	400	2189	2	..	..	3	40	3	60,425	1120	26
13	7	3	..	..	20	58	15	..	1	102	25	..	1	..	..	2	8539		28
..	4101	3800	..	211	2047	590	210	..	1400	600	11	200	..	1	43	..	109,401		43
..	4297	2000	..	5	471	1851	250	..	820	1613	31	200	..	64	31	..	106,803		44
5	651	14	..	1	401	150	40	..	..	402	265	..	..	24	..	..	17,943		45
..	8183	4000	..	2	1546	1740	390	10	200	1053	11	..	..	81	63	..	54,375		46
7	2587	400	..	23	1281	515	330	1	210	3470	214	..	..	212	39	..	34,526		49
..	72	100	..	2	203	125	65	..	..	405	344	..	..	..	3	..	10,186		50
1-METRE STRAMIN NET.																			
1	229	1	44	10	22	..	..	1	..	435	128	..	..	25	12	2	1823	202	8
25	243	3	..	15	23	..	..	1	..	..	..	..	..	5	5	..	710		11
..	70	..	1	..	7	8	..	1	..	6	72	..	..	10	2	9	915		19
..	647	13	85	3	117	43	..	..	..	322	3708	..	..	197	121	..	9241		21
3	148	..	..	35	36	..	..	1	..	2290	3	..	..	2	4	..	3348	4300	26
..	96	10	..	2	121	4	..	..	..	30	46	..	..	3	11	7	1066		28
4	71	11	..	1	22	..	..	4	..	..	1	..	..	..	6	6	2108		29
..	68	52	..	34	51	..	..	2	..	103	20	..	..	10	22	..	1407	270	31
1	905	200	..	71	63	..	..	..	..	42	15	..	..	9	24	..	2168		43
..	1382	350	..	114	189	..	..	..	..	203	25	..	..	22	24	..	3298		44
2	95	22	..	2	29	4	10	1	..	1	23	..	..	4	2	..	380		45
..	894	650	..	66	262	..	..	..	..	205	44	..	..	104	2	..	3494		46
..	436	300	..	19	203	..	..	..	..	350	736	..	..	6	19	1	3316	200	49
8	253	23	..	23	73	3	..	1	..	1	334	..	..	12	19	..	1769		50 (i)
4	182	2	..	..	11	13	..	..	..	1	274	..	..	..	11	1	1065		50 (ii)
FINE SILK NET.																			
..	23	..	5	1	3	..	..	..	200	609	..	..	..	..	1	..	20,043	2	8
2	263	..	1	1	6	285	185	..	200	1	..	..	..	..	..	..	30,143		11
..	35	2	..	..	210	350	854	..	200	342	11	..	..	1401	24	..	9843	10	21
..	233	..	..	1	13	900	895	..	..	770	..	..	..	..	4	2	53,347	125	26
..	68	93	..	..	60	147	406	..	40	301	20	20	..	..	2	..	18,268		43
..	32	19	..	..	43	203	535	..	80	140	20	20	..	40	..	..	5885		44
3	136	85	..	6	253	290	305	..	5	2610	13	100	..	..	16	..	40,300		49
SMALL COARSE NET.																			
..	1	..	..	..	..	..	..	..	..	220	..	..	..	162	9	..	2361		
..	17	..	..	..	386	1060	150	..	..	2000	212	..	..	14	51	..	23,175	550	
..	306	..	..	..	1	32	58	..	..	61	..	..	..	261	6	..	3188		
..	120	..	..	..	..	46	16	..	..	..	..	..	..	80	..	..	402		
..	4186	..	..	..	81	83	101	..	..	180	..	..	..	720	..	..	14,517		
..	199	3	1	..	116	105	125	..	..	400	..	..	..	10	6	..	7668		

Papuan Pass ; O.P.P., outside Papuan Pass ; B.S.N., bottom stramin net ; L.I.A., Low Isles Anchorage ; T.I.L., Three Isles Lagoon ; L.I.F, Low Isles Flat.

TABLE VII.—*Catches in 10-Minute Hauls with the Small Coarse (50 Strands to the Inch) Townet over the Low Isles Reef Flat at High Water.*

Date.	Protozoa.	Medusae, etc.	Siphonophora.	Chaetognatha.	Polychaeta.	Cladocera.	Ostracoda.	Copepoda.	Cirripedia nauplii.	Isopoda.	Amphipoda.	Euphausiacea.	Decapoda larvae.	Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Echinodermata larvae.	Polyzoa, *Cyphonautes.*	Appendicularia.	Thaliacea.	Actinotrocha larvae.	Pisces ova.	Pisces post-larvae.	Total.	Appendicularia houses.
10.viii.28	..	..	..	52	..	..	..	4560	..	..	..	..	1	..	..	..	..	..	..	..	..	60	..	..	40	..	4713	
16.viii.28	..	..	..	38	..	..	..	4004	..	2	..	..	83	..	..	..	..	20	20	60	..	20	..	..	20	..	4267	
25.viii.28	..	..	2	24	..	..	..	1492	..	2	1	..	201	..	..	..	3	60	..	..	..	1520	..	..	301	..	3606	
2.ix.28	..	..	5	62	..	..	140	7193	700	40	22	..	203	..	..	..	..	..	20	20	..	..	..	..	..	..	8405	
10.ix.28	..	..	22	151	..	..	260	3760	..	60	..	20	100	21	..	..	..	100	..	..	..	240	..	..	..	20	4754	
17.ix.28	..	3	44	2	..	..	80	2587	..	120	1	..	41	..	..	..	1	20	..	..	40	540	60	..	40	81	3660	13
25.ix.28	100	20	41	134	..	..	..	942	..	40	..	..	260	..	..	..	..	20	..	..	..	160	..	..	480	2	2199	
29.ix.28	60	..	3	449	3	..	1	4066	..	2	22	2	260	..	..	..	6	184	74	..	..	120	..	..	230	102	5584	3
7.x.28	..	25	92	155	2	..	80	2617	..	..	..	..	145	..	..	..	121	397	93	..	..	1003	368	..	1169	42	6309	+
12.x.28	41	152	128	278	..	..	..	2540	..	..	..	20	161	..	..	..	65	39	17	40	..	668	..	..	203	161	4513	125
22.x.28	..	32	15	132	4	..	..	269	..	..	1	21	54	1	..	..	74	155	423	..	..	2160	3	..	20	49	3413	
30.x.28	..	231	184	436	2	..	20	2360	..	..	..	20	183	..	..	20	210	460	298	40	..	1016	1250	..	340	6	6977	40
8.xi.28	..	5	35	130	10	..	40	750	..	..	..	10	72	..	..	..	10	..	..	..	..	15	..	..	15	10	1102	
13.xi.28	..	42	98	550	1	..	60	2380	..	2	21	140	324	..	..	..	39	65	77	..	..	..	..	..	82	133	4014.	
25.xi.28	..	165	151	245	..	..	40	4535	..	20	..	980	301	20	..	5	22	100	15	..	..	100	..	40	61	1	6801	
3.xii.28	..	21	44	22	..	300	1	561	..	20	1	..	401	..	..	..	20	76	30	2120	..	40	..	..	880	145	4682	
10.xii.28	..	80	64	42	..	..	1	947	120	2	..	..	120	..	..	..	1	14	5	1040	..	101	20	..	100	2	2659	
15.xii.28	..	8	110	54	..	40	..	540	..	22	..	..	70	..	..	..	20	33	38	21	..	..	..	..	120	..	1076	
28.xii.28	..	10	3	41	20	1	..	1290	..	..	..	..	100	..	..	..	26	60	70	20	..	240	..	..	281	22	2184	
5.i.29	..	40	..	4	..	60	1	360	..	40	..	..	21	..	..	..	..	43	23	20	..	..	22	..	..	..	634	
25.i.29	..	..	..	20	..	..	..	700	..	..	..	..	..	..	..	1	..	55	13	..	..	..	..	..	..	..	789	
9.ii.29	..	1	20	44	2	..	..	2080	..	20	..	..	140	1	..	..	..	18	37	..	..	60	..	..	1220	2	3645	
18.ii.29	..	45	123	110	..	380	20	2380	..	20	..	..	44	..	..	23	20	45	21	20	..	251	1	..	80	2	3585	
17.iii.29	..	..	41	242	1	..	20	1440	..	220	..	..	620	..	..	..	20	40	220	20	..	60	..	..	160	21	3125	
26.iii.29	..	140	480	1660	..	..	700	6240	60	60	20	320	626	162	..	..	1	90	92	..	..	400	..	40	120	1	11,212	
1.iv.29	..	188	152	100	1	1	..	6550	..	..	2	150	150	102	..	..	3	33	81	..	..	900	53	..	..	1	8467	
9.iv.29	..	219	5	1000	6	..	700	5700	..	..	208	..	958	341	..	5	119	20	40	..	..	300	100	..	10	9	9810	
18.iv.29	..	41	82	740	1	..	664	4500	20	..	20	120	101	41	..	..	43	23	30	..	..	40	80	..	..	2	6548	
25.iv.29	..	..	80	1120	2	..	2120	10,660	20	62	60	160	1127	202	..	..	425	154	221	..	..	1300	..	..	..	23	17,736	
8.v.29	..	23	..	940	..	..	900	7620	..	..	2	..	262	40	..	..	80	17	67	..	..	321	..	..	40	..	10,312	
16.v.29	..	..	..	120	3	..	160	2360	..	200	140	..	26	1	..	..	8	37	79	..	..	2	..	..	260	1	3397	
22.v.29	..	..	..	660	..	..	3440	12,540	20	..	..	..	83	..	..	..	90	53	147	..	..	760	..	..	100	1	17,894	
8.vi.29	..	1	..	140	..	..	260	1960	..	1	..	..	201	..	..	..	40	8	19	..	..	200	..	..	40	..	2870	
1.vii.29	26	..	..	120	20	..	100	6420	..	2	..	..	3	..	..	..	1	27	51	..	20	540	..	..	280	..	7610	
9.vii.29	14	3	..	240	20	..	60	4560	..	20	..	..	180	20	..	..	20	14	37	..	40	220	..	..	..	..	5448	

TABLE VIII.—*The Vertical Distribution of the Zooplankton in the Barrier Reef Lagoon as Shown by Collections with the Coarse Silk (58 Strands to the Inch) Townet.*

Stations 16, 62 and 68 in daylight : Station 65, at night.

Station No.	Date.	Average depth in metres.	Protozoa.	Medusae, etc.	Siphonophora.	Chaetognatha.	Polychaeta.	Ostracoda.	Copepoda.	Cirripedia nauplii.	Mysidacea.	Cumacea.	Amphipoda.	Euphausiacea.	Decapoda larvae.	Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Cephalopoda young.	Echinodermata larvae.	Polyzoa, *Cyphonautes.*	Appendicularia.	Thaliacea.	Amphioxus larvae.	Pisces ova.	Pisces post-larvae.	Total.
16	3.xi.28	*S.*	1	1	2	28	..	..	1314	..	..	..	2	24	33	2	..	10	1	195	5	..	..	..	..	203	..	166	48	2035
	,,	3·1	..	94	55	440	7	..	3676	..	..	..	7	131	206	2	..	2	19	960	35	..	100	..	200	65	..	57	104	6150
	,,	8·0	..	583	133	1852	28	..	24,850	..	1	..	..	1101	2166	10	..	1	19	3250	360	..	200	..	401	2614	..	33	117	37,701
	,,	11·1	..	90	770	1324	22	..	56,510	..	..	..	30	1451	1187	10	..	3	103	2010	640	1	1	..	3800	954	..	36	523	65,466
	,,	12·5	..	23	374	1112	14	..	54,401	..	..	..	51	2592	2667	22	..	2	167	2250	1240	..	..	..	201	2609	..	22	74	67,822
	,,	16·5	..	30	1387	893	45	10	37,491	..	..	..	294	750	963	..	..	7	41	2320	980	1	..	200	1425	423	..	207	71	47,538
62	15.vi.29	*S.*	..	1	95	140	1	40	1920	..	..	..	2	..	10	..	..	..	153	2920	520	..	..	..	80	..	..	..	..	5882
	,,	4·0	..	482	300	3800	38	3800	36,400	..	1	..	70	100	375	20	1	1	460	1320	1330	..	..	..	820	13	..	..	13	49,346
	,,	7·5	..	620	80	5400	34	14,800	52,000	..	20	..	650	190	2600	90	1	10	842	1160	1900	..	..	..	1021	27	..	..	42	81,485
	,,	12·5	..	350	31	5400	56	9800	50,600	..	41	..	1190	1400	5765	630	21	27	582	970	750	1	..	..	800	13	..	..	120	78,547
	,,	16·0	..	70	100	4800	530	22,800	35,200	..	130	..	2000	60	2071	60	340	14	1310	800	2250	1	..	800	1400	..	..	..	230	74,966
	,,	21·0	..	131	100	2600	90	10,600	23,000	..	80	..	410	180	1340	60	90	5	650	1220	1830	..	..	200	1010	10	..	..	40	43,646
65	10.vii.29	*S.*	..	4	35	400	..	400	33,600	..	230	4	104	10	771	50	1600	31	2	110	640	..	..	..	800	2	..	..	8	38,800
	,,	3·7	..	73	30	1000	33	1800	55,800	..	70	54	240	1	680	110	1000	14	23	150	520	..	..	20	3400	1	1	3	80	65,103
	,,	8·0	..	49	23	1000	5	4830	69,600	..	390	33	310	1	880	19	800	..	23	210	1050	..	..	..	2600	1	2	2	110	81,938
	,,	12·5	..	34	12	1000	7	1809	58,600	..	60	44	121	..	890	60	100	4	42	130	590	1	..	..	1800	..	2	1	50	65,357
	,,	15·5	..	12	39	800	28	3040	52,800	400	70	72	141	..	1071	23	170	5	16	290	1330	..	..	..	1600	..	1	..	90	61,998
	,,	20·7	..	7	5	1200	1	2230	42,600	..	18	30	122	1	3971	60	130	100	2	290	910	1	..	200	600	..	..	..	60	52,538
68	18.vii.29	*S.*	1	1	9	125	..	..	6800	..	..	..	2	..	27	..	..	..	..	200	10	..	..	..	5	2	..	..	..	7182
	,,	3·5	200	21	17	750	..	400	18,600	..	..	..	20	..	706	1	..	..	59	1130	70	1	..	..	600	..	..	..	18	22,593
	,,	7·5	..	30	21	660	2	600	27,600	..	..	..	51	8	2781	6	11	8	27	480	470	..	..	..	400	3	..	..	21	33,179
	,,	12·0	..	18	40	590	1	5000	23,800	..	1	..	88	4	6421	60	20	30	2	740	490	..	..	..	1200	2	..	1	30	38,538
	,,	16·5	..	3	20	1200	5	6200	41,600	..	2	..	160	10	11,630	90	130	30	34	600	870	..	..	..	600	7	..	..	21	63,212
	,,	20·7	..	1	60	1410	3	3200	23,200	..	8	..	90	9	4611	70	220	13	31	590	1860	3	..	..	400	6	..	2	36	35,823

TABLE IX.—*The Average Catches for Each Month in the Oblique Hauls with the Coarse Silk,* 1-*Metre*
(Calculated from

	Protozoa.	Medusae, etc.	Siphonophora.	Coral planulae.	Planaria.	Nemertini.	Chaetognatha.	Polychaeta.	Cladocera.	Ostracoda.	Copepoda.	Cirripedia nauplii.	Mysidacea.	Isopoda.	Amphipoda.	Euphausiacea larvae.	Euphausiacea adults.
Coarse Silk.																	
July, 1928	25	45	546	..	..	..	1013	1		1000	156,804	..	4	..	187	6205	2
Aug., ,,	1	77	371	..	..	..	1198	41	..	1160	82,650	..	48	..	681	311	3
Sept., ,,	301	22	416	..	..	..	372	54	..	50	35,618	200	1	..	94	1145	1
Oct., ,,	600	264	1258	..	+	..	1769	220	..	1324	61,783	67	+	..	86	1009	1
Nov., ,,	160	211	1525	..	+	..	2308	93	..	140	28,810	..	..	..	96	784	1
Dec., ,,	105	886	2720	768	1	..	2420	401	402	1152	50,667	300	..	..	18	155	..
Jan., 1929	55	732	4699	..	..	..	3136	125	700	1650	77,320	..	..	..	514	350	..
Feb., ,,	..	72	2503	..	..	..	3200	101	810	210	65,901	67	..	..	321	407	..
Mar., ,,	..	409	2437	..	..	..	6400	141	..	1467	104,867	267	..	..	553	2200	..
April, ,,	..	1296	572	..	..	..	4700	189	..	12,150	69,850	250	..	..	405	1960	1
May, ,,	..	176	182	..	..	..	5600	54	..	27,450	62,950	50	123	..	620	16	2
June, ,,	..	330	66	..	..	..	5467	97	..	7533	50,334	..	21	..	247	40	1
July, ,,	1	90	125	..	..	..	1500	7	..	2000	73,300	100	25	..	100	4	1
1-Metre Stramin.																	
July, 1928	30	11	510	..	..	..	720	..	..	..	2210	..	3	+	80	15	2
Aug., ,,	4	51	1204	..	..	..	925	..	..	..	1928	..	11	..	176	20	4
Sept., ,,	1	17	357	..	..	..	231	4	..	..	477	..	2	..	34	18	5
Oct., ,,	+	36	433	..	..	..	451	3	..	..	675	..	..	..	29	32	+
Nov., ,,	1	102	821	..	..	+	252	2	..	..	587	..	+	..	52	8	+
Dec., ,,	+	445	3058	..	..	..	1148	214	..	50	1269	..	..	..	50	16	..
Jan., 1929	..	222	1211	..	..	..	255	12	..	..	733	..	..	..	38	..	..
Feb., ,,	..	229	440	..	..	..	123	+	..	..	231	..	..	..	5	..	..
Mar., ,,	..	286	653	..	..	..	442	..	..	..	190	..	..	..	15	..	..
April, ,,	..	109	301	..	..	..	1192	4	..	..	1108	..	..	..	70	4	..
May, ,,	..	207	560	..	..	..	2075	12	..	50	2028	..	22	..	190	5	2
June, ,,	6	47	103	..	..	..	1600	1	..	..	796	..	4	..	223	56	3
July, ,,	3	46	83	..	..	..	947	+	..	..	5467	..	38	..	87	36	5
Fine Silk.																	
July, 1928	6	5	34	..	..	..	156	1	..	200	26,360	..	1	..	9	450	1
Aug., ,,	..	13	15	..	..	..	107	40	..	140	59,991	..	5	..	15	19	+
Sept., ,,	334	4	6	..	..	..	202	278	..	..	32,907	67	1	..	2	130	..
Oct., ,,	200	253	92	..	..	..	351	114	..	133	22,932	..	..	..	2	53	..
Nov., ,,	50	235	87	..	..	..	104	259	..	4	26,157	..	..	..	5	87	1
Dec., ,,	..	259	226	310	29	..	407	443	54	296	27,305	..	..	..	+	5	..
Jan., 1929	1	156	141	..	..	..	276	340	..	125	14,195	..	..	..	8	25	..
Feb., ,,	..	181	254	..	..	..	723	511	+	+	42,393	313	..	..	8	..	..
Mar., ,,	..	206	138	..	..	..	1207	190	..	160	34,947	..	..	..	19	..	..
April, ,,	1	648	5	..	..	..	1802	299	..	1543	44,650	1	..	..	19	225	+
May, ,,	..	77	2	..	..	..	1150	232	..	2525	30,600	..	2	..	33	1	+
June, ,,	..	153	7	..	..	..	860	243	..	1233	53,100	..	2	..	34	3	2
July, ,,	..	21	3	..	..	..	400	3	..	433	37,233	..	1	..	7	..	2

Stramin, and Fine Silk Townets at the Stations in the Barrier Reef Lagoon 3 Miles East of Low Isles.
Tables II, III and IV).

Decapoda larvae.	Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Cephalopoda young.	Echinodermata larvae.	Polyzoa, *Cyphonautes.*	Appendicularia.	Thaliacea.	Tornaria larvae.	Amphioxus larvae.	Pisces ova.	Pisces post-larvae.	*Incertae sedis.*	Total.	Appendicularia houses.
Coarse Silk.																		
289	35	56	1	92	1770	2260	..	..	..	791	6	..	..	2	21	1	171,156	
2345	19	30	35	64	1966	1934	+	120	..	1383	97	..	..	19	33	..	94,586	216
924	6	1	4	71	1055	577	+	200	..	1191	462	..	..	491	45	..	43,292	42
2278	1	12	10	803	2270	1063	1	400	..	2828	5553	..	..	332	345	..	84,277	50
2000	19	+	7	1343	1000	224	+	21,874	..	6052	4456	..	..	159	179	8	71,447	4266
2436	104	..	83	1993	1135	340	+	87,003	..	3512	1106	52	..	116	167	3	158,045	
2305	981	2	85	1553	366	480	..	3900	..	12,059	1466	..	..	102	136	5	112,721	11,950
2708	1253	8	11	671	663	887	1	743	..	7653	134	..	..	139	268	5	88,736	4467
2865	1631	..	21	1227	1017	2337	..	1083	..	4466	85	200	..	1	59	1	133,734	
2594	1433	9	23	1123	1380	1127	+	..	..	3665	4363	..	..	1	265	1	107,619	850
2196	95	32	39	626	770	1080	3	100	300	3441	3395	..	..	1	165	..	109,665	
1463	183	16	15	469	703	1227	4	3	400	2610	112	..	..	7	102	..	71,450	
2194	35	85	25	17	250	1900	13	200	100	4515	13	..	..	3	23	..	86,626	
1-Metre Stramin.																		
918	63	65	10	53	..	..	..	..	..	119	11	..	..	9	6	..	4835	
1719	18	42	53	60	9	..	1	..	..	390	94	..	..	40	24	..	6773	698
216	10	2	3	35	+	..	..	..	..	199	1212	..	..	127	18	..	2970	102
412	4	2	9	132	+	..	+	..	..	318	2206	..	..	89	35	2	4901	160
217	4	5	16	105	15	..	..	..	..	536	6718	..	..	118	19	+	9593	2597
1055	146	..	115	238	382	..	..	37,150	..	446	2733	..	..	35	66	+	48,616	440
245	161	..	59	510	2	..	+	1870	..	1318	2797	..	..	10	31	+	9475	2700
247	90	+	55	171	2	..	+	..	..	843	105	..	..	70	38	+	2650	270
350	110	..	75	185	5	..	+	..	..	167	29	..	..	17	32	..	2856	
1225	221	10	68	282	21	..	..	..	..	273	28,164	..	..	5	32	..	33,089	425
1142	155	48	80	254	26	..	..	..	..	29	14,074	..	..	4	51	..	21,014	
1834	127	5	33	114	4	..	1	..	..	117	57	..	..	3	16	..	5150	
1381	12	145	12	37	+	..	1	67	..	243	26	..	..	3	18	1	8659	500
Fine Silk.																		
13	12	1	..	11	..	..	..	..	..	64	1	..	..	..	1	..	27,326	
129	1	5	6	7	22	62	+	80	..	531	4	..	..	1	4	..	61,197	134
22	4	1	..	2	930	307	..	..	..	515	77	..	..	8	13	..	35,810	
441	2	2	+	658	712	1182	..	2	..	1173	46	..	..	135	75	..	28,558	13
63	+	..	1	569	492	23,228	..	2744	..	572	259	..	..	1	19	2	54,739	216
120	3	..	1	644	208	380	+	3135	..	748	43	..	..	50	19	..	34,685	
66	29	+	1	776	78	505	..	225	..	778	53	25	..	..	7	..	17,812	482
64	21	..	2	476	237	1213	+	67	..	1929	7	..	..	+	18	..	48,417	1807
243	44	..	3	402	440	1470	..	193	..	1013	8	..	..	..	10	..	40,693	113
210	47	8	1	1194	514	796	..	25	..	2553	62	25	..	+	15	..	54,643	+
130	8	3	2	430	292	666	..	..	..	1183	295	..	26	75	7	..	37,739	
61	11	2	2	417	1402	1490	..	3	33	1801	1	..	..	..	7	..	60,867	
135	4	8	+	2	67	213	..	..	..	987	1	..	..	2	1	..	39,523	

TABLE X.—*The Average Catches for Each Month in the Vertical Hauls with the Coarse Silk Townet at the Stations in the Barrier Reef Lagoon 3 Miles East of Low Isles. (Calculated from Table V).*

	Protozoa.	Medusae, etc.	Siphonophora.	Coral planulae.	Chaetognatha.	Polychaeta.	Cladocera.	Ostracoda.	Copepoda.	Cirripedia nauplii.	Isopoda.	Mysidacea.	Amphipoda.	Euphausiacea.	Decapoda larvae.	Sergestidae.	*Leptochela pugnax.*	Stomatopoda larvae.	Pteropoda and Heteropoda.	Gastropoda larvae.	Lamellibranchia larvae.	Echinodermata larvae.	Polyzoa, *Cyphonautes.*	Appendicularia.	Thaliacea.	Actinotrocha larvae.	Tornaria larvae.	Pisces ova.	Pisces post-larvae.	Total.
Aug., 1928	..	9	29	..	83	..	..	100	4888	7	..	8	38	2	97	1	3	1	4	44	47	..	..	135	1	..	..	1	3	5501
Sept., ,,	30	3	14	..	36	10	..	15	1984	10	..	..	1	40	30	..	..	..	4	199	89	..	..	157	10	..	..	34	11	2677
Oct., ,,	..	35	55	..	151	1	..	47	2231	..	..	..	8	34	58	..	..	..	109	594	268	..	..	155	52	..	..	8	2	3808
Nov., ,,	..	31	47	..	140	33	..	19	1728	..	..	..	14	6	143	1	1	..	52	147	52	464	..	169	164	..	..	13	15	3239
Dec., ,,	..	164	128	45	290	102	45	55	2464	..	..	..	1	22	86	31	..	1	120	58	101	1376	..	480	52	5	..	5	8	5639
Jan., 1929	..	50	119	..	157	4	..	33	9170	1	..	..	5	..	143	43	2	1	144	27	35	67	..	952	25	..	67	2	37	11,084
Feb., ,,	..	58	224	..	320	77	7	27	5047	60	..	..	10	..	276	62	1	8	35	21	45	80	..	792	10	34	..	2	3	7199
Mar., ,,	..	54	83	..	467	36	..	147	6620	33	..	..	24	..	177	16	1	7	56	52	164	60	..	520	44	7	..	..	7	8575
April, ,,	..	175	51	..	455	17	5	575	5040	10	..	..	21	1	197	40	1	1	90	66	97	15	..	417	96	10	..	..	2	7382
May, ,,	..	16	4	..	261	1	..	830	3055	5	..	1	33	..	97	4	..	1	36	44	103	5	..	166	36	..	..	10	2	4710
June, ,,	..	92	1	..	390	42	..	390	2690	..	..	..	17	1	60	11	1	..	37	74	78	..	..	190	1	..	..	..	..	4075
July, ,,	..	3	5	..	71	1	..	380	3530	..	..	3	5	..	99	..	7	2	..	5	52	..	..	173	..	..	..	..	1	4337

TABLE XI.—*The Average Catches for Each Month in the Ten-Minute Hauls with the Small Coarse Townet over the Low Isles Reef Flat at High Water. (Calculated from Table VII).*

Aug., 1928	..	..	1	..	38	..	..	..	3352	..	1	..	+	..	95	..	..	..	1	27	6	20	..	533	..	..	..	120	..	4194
Sept., ,,	32	5	23	..	160	1	..	96	3709	140	52	..	9	4	173	4	..	..	1	65	19	4	8	212	12	..	..	150	41	4920
Oct., ,,	10	110	105	..	250	2	..	25	1946	..	..	..	+	15	136	+	..	5	118	263	208	20	..	1212	405	..	..	433	65	5328
Nov., ,,	..	71	95	..	308	4	..	47	2555	..	7	..	7	377	232	7	..	2	24	55	31	..	..	38	..	13	..	52	48	3973
Dec., ,,	..	30	55	..	40	5	85	1	835	30	11	..	+	..	173	..	..	..	17	46	36	800	..	95	5	..	..	345	42	2651
Jan., 1929	..	20	..	..	12	..	30	1	530	..	20	..	..	..	11	..	..	1	..	49	18	10	..	..	11	..	..	..	..	713
Feb., ,,	..	23	72	..	77	1	190	10	2230	..	20	..	..	..	92	1	..	12	10	32	29	10	..	156	1	..	..	650	2	3618
Mar., ,,	..	70	261	..	951	1	..	360	3840	30	140	..	10	160	623	81	..	..	11	65	156	10	..	230	..	20	..	140	11	7170
April, ,,	..	112	80	..	740	3	+	871	6852	10	16	..	73	108	584	172	..	1	148	58	93	..	..	635	58	..	..	3	9	10,626
May, ,,	..	8	..	..	573	1	..	1500	7507	7	67	..	47	..	124	14	..	..	59	36	98	..	..	361	..	..	..	133	1	10,536
June, ,,	..	1	..	..	140	..	..	260	1960	..	1	..	..	..	201	..	..	..	40	8	19	..	..	200	..	..	..	40	..	2870
July, ,,	20	2	..	..	180	20	..	80	5490	..	11	..	..	..	92	10	..	..	11	21	44	..	30	380	..	..	..	140	..	6531

REFERENCES.

BIGELOW, HENRY B. 1926. Plankton of the Offshore Waters of the Gulf of Maine. Bull. U.S. Bur. Fish. Washington, XL, 1924, Pt. II, pp. 1–509, 134 text illust.

BULLETIN PLANKTONIQUE pour les Années 1908–1911, Deuxième Partie contenant les Listes Planktoniques des Recherches quantitatives pour les Années 1910–1911. Conseil Perm. Int. Explor. Mer., 1914, pp. 69–136.

DELSMAN, H. C. 1921. Fish Eggs and Larvae from the Java Sea. Treubia, II, pp. 97–108, 8 text illust., 1 chart.

—— 1926. Fish Eggs and Larvae from the Java Sea. Treubia, VIII, pp. 199–239, 35 text illust.

FARRAN, G. P. 1927. The Reproduction of *Calanus finmarchicus* off the South Coast of Ireland. J. Cons. Perm. Int. Explor. Mer., II, pp. 132–143, 2 text illust.

GARDINER, A. C. 1931. The Validity of Single Vertical Hauls of the International Net in the Study of the Distribution of the Plankton. J. Mar. Biol. Ass. U.K., N.S. XVII, pp. 449–472, 2 text illust.

HARVEY, H. W. 1934. Measurement of Phytoplankton Population. J. Mar. Biol. Ass. U.K., N.S. XIX, pp. 761–773, 9 text illust.

HERDMAN, W. A., and SCOTT, ANDREW. 1913. An Intensive Study of the Marine Plankton around the South End of the Isle of Man.—Part VI. Proc. Lpool. Biol. Soc., XXVII, pp. 372–408, 1 pl., 5 text illust.

KRÄMER, AUGUSTIN. 1897. Ueber den Bau der Korallenriffe und die Planktonvertheilung an den Samoanischen Küsten nebst vergleichenden Bemerkungen. Kiel u. Leipzig, pp. 1–163, text illust.

LEBOUR, MARIE V. 1922. The Food of Plankton Organisms. J. Mar. Biol. Ass. U.K., N.S. XII, pp. 644–677, 3 text illust.

—— 1923. The Food of Plankton Organisms: II. J. Mar. Biol. Ass. U.K., N.S. XIII, pp. 70–92, 12 text illust.

LOHMANN, H. 1908. Untersuchungen zur Feststellung des vollständigen Gehaltes des Meeres an Plankton. Wiss. Meeresuntersuch. Kiel, X, pp. 131–370, pls. ix–xvii, 22 text illust., tables A and B.

LÜCKE, F. R. 1912. Quantitative Untersuchungen an dem Plankton bei dem Feuerschiff "Borkumriff" im Jahre 1910. Wiss. Meeresuntersuch. Kiel, XIV, pp. 103–128, 3 text illust.

MOORE, HILARY B. 1931. The Muds of the Clyde Sea Area. III: Chemical and Physical Conditions; Rate and Nature of Sedimentation; and Fauna. J. Mar. Biol. Ass. U.K., N.S. XVII, pp. 325–358, 11 text illust.

RUSSELL, F. S. 1925. The Vertical Distribution of Marine Macroplankton. An Observation on Diurnal Changes. J. Mar. Biol. Ass. U.K., N.S. XIII, pp. 769–809, 1 pl., 6 text illust.

—— 1933. The Seasonal Distribution of Macroplankton as Shown by Catches in the 2-metre Stramin Ring-trawl in Off-shore Waters off Plymouth. J. Mar. Biol. Ass. U.K., N.S. XIX, pp. 73–82.

—— 1934. The Vertical Distribution of Marine Macroplankton. XII: Some Observations on the Vertical Distribution of *Calanus finmarchicus* in Relation to Light Intensity. J. Mar. Biol. Ass. U.K., N.S. XIX, pp. 569–584, 3 text illust.

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THE ZOOPLANKTON

IV. THE OCCURRENCE AND SEASONAL DISTRIBUTION OF THE TUNICATA, MOLLUSCA AND COELENTERATA (SIPHONOPHORA)

BY

F. S. RUSSELL, D.S.C., B.A., AND J. S. COLMAN, B.A.

WITH THIRTY TEXT-FIGURES.

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TUNICATA

The pelagic Tunicates (Tables I, II and III, pp. 232–234) formed an important part of the larger plankton, but among the great number of small animals retained by the silk nets they were less important. On the average the tunicates formed one-half of the total number of animals caught in the stramin net, while in the coarse and fine silk nets, oblique hauls, these proportions were only 5·7% and 2·7% respectively. We give below the percentages of the total animals formed by the tunicates for the different nets on the average for each month in the barrier reef lagoon.

Number of Tunicates as Percentage of Total Animals Caught in each Month.

	Oblique hauls.		
	Stramin.	Coarse silk.	Fine silk.
1928 :			
July	2·7	0·5	0·2
August	7·1	1·6	0·9
September	47·5	3·8	1·7
October	52·1	9·9	4·3
November	75·7	14·7	1·5
December	6·5 or 27·7*	2·9	2·3
1929 :			
January	43·5 or 54·1*	12·0	4·7
February	36·4	8·8	4·0
March	6·9	3·4	2·5
April	85·9	7·7	4·8
May	67·1	6·4	3·9
June	3·4	3·8	3·0
July	3·1	5·2	2·5
Average for year (based on average catch for each month)	52·1*	5·7	2·7

It is quite evident that in the stramin net catches the tunicates played an important part, reaching as much as 85·9% of the average catch for the month of April. In the coarse silk net by contrast the greatest percentage is only 14·7% in November.

---

* Excluding Echinoderm larvae, which are not retained in the stramin net under normal circumstances, but here occurred owing to excessive swarms.

We give below the percentage for each month of Doliolids, Salps and Appendicularians for the stramin and coarse silk nets.

Percentage Composition of Average Monthly Catches of Tunicates.

	Oblique hauls.					
	Stramin.			Coarse silk.		
	Doliolids.	Salps.	Appendicularians.	Doliolids.	Salps.	Appendicularians.
1928 :						
July	6·2	2·3	91·5	..	0·7	99·3
August	10·9	8·5	80·5	6·4	0·2	93·4
September	1·1	84·8	14·1	0·2	27·8	72·0
October	1·3	86·1	12·6	1·3	64·9	33·7
November	0·2	92·4	7·4	..	42·4	57·6
December	8·6	77·4	14·0	10·0	13·9	76·1
1929 :						
January	0·5	67·5	32·0	2·3	8·7	89·0
February	2·6	9·5	88·9	1·4	0·3	98·5
March	12·9	2·0	85·1	1·9	..	98·1
April	0·2	98·8	1·0	3·3	51·1	45·6
May	0·3	99·5	0·2	2·9	46·8	50·3
June	31·4	1·7	7·2	3·9	0·2	95·8
July	9·3	0·4	90·3	0·3	..	99·7
Average for year (based on average catch for each month)	1·1	91·0	7·9	2·3	26·3	71·4

These figures show that on the average for the year the Thaliacea far outnumbered the Appendicularians in the stramin catches, but that there were violent fluctuations in the composition of the Tunicata, which we shall see later were due to swarming of certain species, notably *Salpa democratica* and *Megalocercus huxleyi*. In the coarse silk net, however, the Appendicularians preponderated, except in months when swarms of Salps were met with ; these Appendicularians were nearly all of a small size not retained in great numbers by the stramin net. In both nets the Doliolids were on the whole of very small significance.

The identification of the pelagic tunicates has been done by Miss A. B. Hastings, and the list of species observed is given in her report on the Tunicata in Volume IV of these Reports* (1931, p. 105). The total collections comprised 3 species of Doliolids, 6 species of salps, and 8 species of Appendicularians, but the only species which played an important part in the composition of the plankton at the weekly station were *Salpa democratica*, *Oikopleura rufescens* and perhaps *Oikopleura longicauda*.

From the proportional occurrence of the species in the samples examined by Miss Hastings and from notes made by us while examining the complete catches, it has been possible to apportion the numbers of tunicates in each catch amongst the various species present. The resulting figures are given in Tables I, II and III (pp. 232–234). While it must be realized that these figures cannot be regarded as strictly accurate, it is most probable that they represent a fair picture of the occurrence of the tunicates in our collection, since we have exercised considerable judgment in producing them, and when in doubt have always had larger samples examined by Miss Hastings. We are very grateful to her for the help she has given in this respect.

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* To that list must now be added *Doliolum gegenbauri*, *Fritillaria pellucida* and *Fritillaria borealis truncata* (see pp. 208 and 225).

THALIACEA.

Family Doliolidae, Bronn.

Three species of Doliolids were recorded, namely *Doliolum denticulatum*, Q. and G., *Doliolum tritonis*, Herdman, and *Doliolum gegenbauri*, Ulianin. Of these *D. gegenbauri** is recorded for the first time from the Pacific Ocean, and *D. tritonis* for the first time from this region of the Pacific. All species occurred at the weekly station in the barrier reef lagoon, but *D. denticulatum* was easily the most abundant.

Genus *Doliolum*, Q. and G.

Doliolum denticulatum, Q. and G.

Individuals of the phorozooid and gonozooid generations of *D. denticulatum* were present throughout the year in the barrier reef lagoon. In Text-fig. 1 are given the curves for the average catches for each month for all three nets for all Doliolids. (On account of the great preponderance of *D. denticulatum* these curves practically represent the results for this species.) They show a large increase in December, which is sustained, especially by the coarse silk net, oblique hauls, until June, with decreases in February and March. (The numbers caught in the coarse silk net, vertical hauls, were rather too small to give significant results, but they also showed an increase between November and April.) A closer analysis shows that this increase is due to the presence of very small individuals in the catches. At a number of stations some Doliolids occurred of so small a size that it was necessary to count them in the 1/200 samples. These small individuals occurred at the following stations, the numbers in brackets being the number recorded at each station: Coarse silk, oblique, Stations 7 (400), 15 (200), 34 (1400), 35 (200), 36 (200), 37 (400), 39 (600), 42 (200), 47 (200), 52 (200), 53 (600), 56 (600), 60 (200), and stramin, oblique, Station 32 (600). They occurred mostly during the months from December to June. In Text-fig. 2 are given the curves for the monthly average abundance of Doliolids in the coarse silk and stramin nets, oblique hauls, excluding these very small forms; it shows that the large and medium-sized individuals were much more evenly distributed throughout the year. There was also perhaps a tendency for them to be more consistently abundant in April, May and June. On the whole gonozooids were rather more abundant than phorozooids.

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* Since writing this, *D. gegenbauri* has been recorded by Garstang (1933) from the South Pacific in the collections of the British Antarctic ("Terra Nova") Expedition, 1910.

As regards the occurrence of blastozooids,* there was quite definitely a tendency for their presence in the catches to coincide with the period at which the small Doliolids were so abundant. It is presumed that many belonged to *D. denticulatum*, but the larger ones were too old for identification. Probably many small nurse-forms were also present at times among the small unsorted individuals.

This species was usually present in collections from outside the Barrier (Table III), and appears to have been rather abundant in February and March in the regions of Cook's Passage and Papuan Pass.

Doliolum tritonis, Herdman.†

Tables I and II show that the phorozooids and gonozooids of *D. tritonis* occurred very rarely in the collections from the weekly station in the barrier reef lagoon. It seems to have become suddenly abundant in December and early January. Up to that time one specimen had been recorded from the stramin net from Station 24 (6.xi.28), and one from the coarse silk net at Station 22 (23.x.28). The only other catch was at Station 52 (6.iv.29) in the coarse silk net. At stations other than the weekly one *D. tritonis* was not common, being recorded only from one coarse silk net and three stramin net catches (Table III).

Doliolum gegenbauri, Ulianin.†

D. gegenbauri was recorded on only two occasions, both at the weekly station in the lagoon, Station 34 (19.xii.28) and Station 47 (4.iii.29), in the coarse silk net. It is possible that it may have occurred on other occasions among the very small individuals that were not sorted, but the species appears like *D. tritonis* to be of small importance compared with *D. denticulatum*.

On the Occurrence of Doliolids.

On the Siboga Expedition (Ihle, 1910) four species of Doliolids were recorded: *Anchinia rubra*, Vogt, *Doliolum tritonis*, Herdman, *D. nationalis*, Borgert, and *D. denticulatum*, Q. and G. Of these, *D. denticulatum* was by far the most frequent species in the collections, and *D. tritonis* was second. *D. denticulatum* is given by Neumann (1906) as the most frequent of all *Doliolum* species. In the Pacific *D. tritonis* has been recorded by Ritter (1905) as the most abundant species off San Diego. On the whole the Pacific does not appear to be so rich in *Doliolum* species as other oceans, although the appearance of *D. gegenbauri* in these collections leads one to suppose that further collections may show the presence of more species.

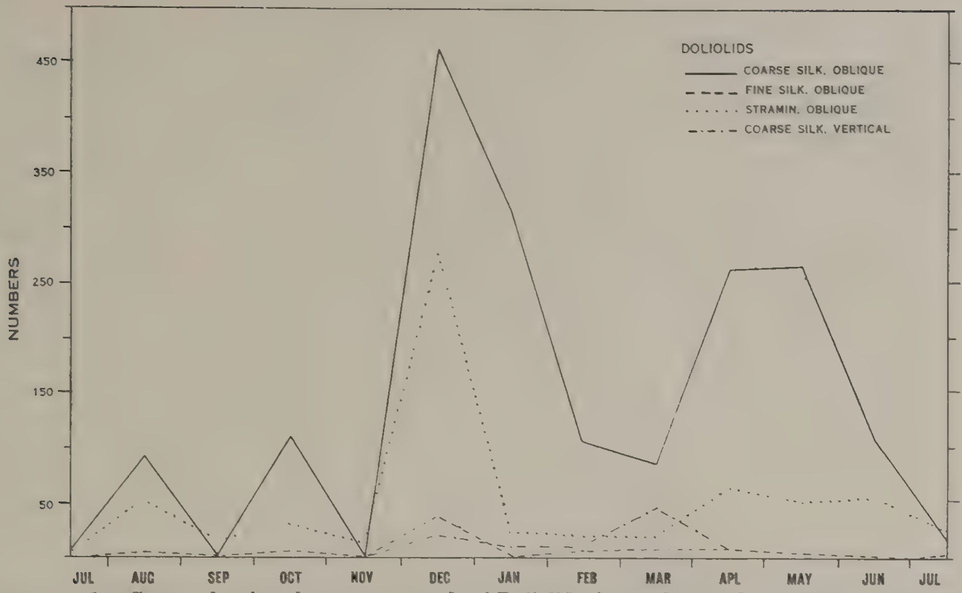
Little appears to be known of the seasonal occurrence of Doliolids.

Vertical Distribution.—Doliolids only occurred at two of the vertical distribution stations in sufficient numbers to give significant results. At both these stations, which were taken in the lagoon in daylight in October and June, the Doliolids avoided the surface layers. They were evidently affected by the transparency of the water, their depths of

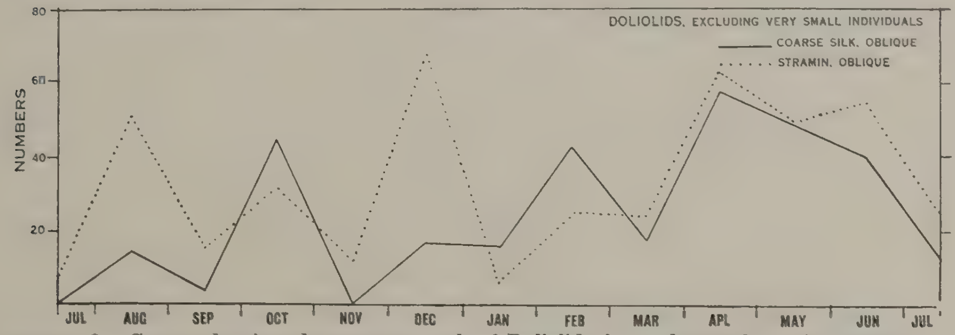
---

* Blastozooids occurred as follows: Coarse silk oblique, Station 35, 2; Station 37, 1; Station 41, 1; Station 47, 1; Station 53, 1; Station 58, 1; Station 60, 1. Stramin, oblique, Station 30, 1; Station 32, 5; Station 34, 1; Station 35, 8; Station 37, 3; Station 47, 4; Station 59, 1; Station 60, 1.

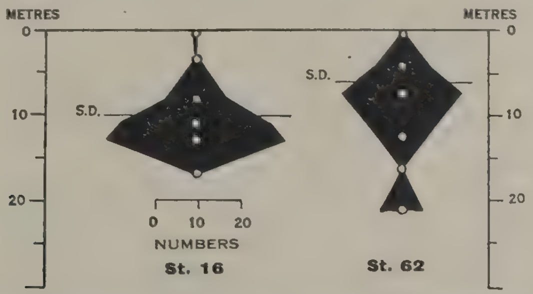
† These species have recently been removed by Garstang (1933) to the genus *Dolioletta*.



Text-fig. 1.—Curves showing the average catch of Doliolids for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. These consist mostly of the phorozooids and gonozooids of *D. denticulatum*. (Coarse and fine silk, and stramin nets, oblique hauls; and coarse silk net vertical hauls.)



Text-fig. 2.—Curves showing the average catch of Doliolids for each month at the position 3 miles east of Low Isles in the barrier reef lagoon, when the very small individuals have been excluded. (Coarse silk and stramin nets, oblique hauls.)



Text-fig. 3.—The vertical distribution of Doliolids, mostly *D. denticulatum*, in the daylight in the barrier reef lagoon. Station 16 (3.x.28), 10.13 a.m. to 12.27 p.m.; Station 62 (15.vi.29), 11.20 a.m. to 1.45 p.m. The circles and white dots indicate the average depths at which the hauls were made. Coarse silk townet. S.D., Secchi disc reading.

maximum abundance being at about 12 metres when the Secchi disc reading was 10 m., and at about 7·5 metres when the reading was 6 m. It is unlikely that their depth distribution will have affected the results given above on their seasonal distribution as shown by the oblique hauls, except perhaps on days when the water was unusually clear. On both occasions their numbers diminished greatly in the deepest layers sampled at the vertical distribution stations (see Text-fig. 3). *Doliolum denticulatum* alone occurred at Station 16. The actual numbers in the catches were as follows :

Station **16**.		Station **62**.		Station **65**.		Station **68**.	
S.	1	*S.*	..	*S.*	2	*S.*	..
3·1 m.	..	4·0 m.	13	3·7 m.	1	3·5 m.	..
8·0 ,,	14	7·5 ,,	27	8·0 ,,	1	7·5 ,,	2
11·1 ,,	34	12·5 ,,	11	12·5 ,,	..	12·0 ,,	2
12·5 ,,	41	16·0 ,,	..	15·5 ,,	..	16·5 ,,	7
16·5 ,,	1	21·0 ,,	10	20·7 ,,	..	20·7 ,,	6

Although the numbers are very low there is an indication that the Doliolids came to the surface in the dark at Station 65.

Family Salpidae, Forbes.

Six species of Salps were recorded : *Cyclosalpa pinnata* (Forskål), *Salpa democratica*, Forskål, *Salpa zonaria* (Pallas), *Salpa cylindrica*, Cuvier, *Salpa confoederata*, Forskål, and *Salpa rostrata*, Traustedt.

S. rostrata is here recorded for the first time from the Pacific. *S. democratica* was easily the most abundant species. All occurred at the weekly station three miles east of Low Isles, except *S. zonaria*, which was only taken outside Trinity Opening.

Genus *Cyclosalpa* (de Blainville).

Cyclosalpa pinnata (Forskål).

C. pinnata was only taken once at the weekly station in the lagoon, namely at Station 2 (30.vii.28), when one aggregate individual was taken in the stramin net.

Four other specimens were caught, a solitary individual at Station 19 (20.x.28) outside Trinity Opening, and 3 aggregate individuals at Station 50 (18.iii.29) outside Papuan Pass in the stramin net from 170 metres.

Genus *Salpa*, Forskål.

Salpa democratica, Forskål.

S. democratica, " the commonest Salp in warm waters " (Apstein, 1906, p. 270), was easily the most abundant and most frequent salp in our collections. Calculation of the average monthly abundance at the weekly station in the Barrier Reef lagoon shows that there were two periods of the year at which these Salps were especially frequent, namely during the months September to January, and in April and May. During the remaining months of the year, June to August and February and March, they were almost completely absent.

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A more detailed analysis (Text-figs. 4 and 5) shows also that during the months of greatest abundance it was only on a few days that really large catches were made. At these periods the Salps could often be seen in the sea in enormous numbers, and many were washed up on the beach at Low Isles. Text-figs. 4 and 5 show also that on the whole the curves for the stramin and coarse silk net oblique hauls agree fairly closely. On 2nd October, however, a very large catch was made by the coarse silk net, while very few were caught in the stramin net. On 2nd November the two nets caught approximately the same numbers, while on 6th November and on all subsequent occasions the stramin net caught more than twice as many as the coarse silk net.

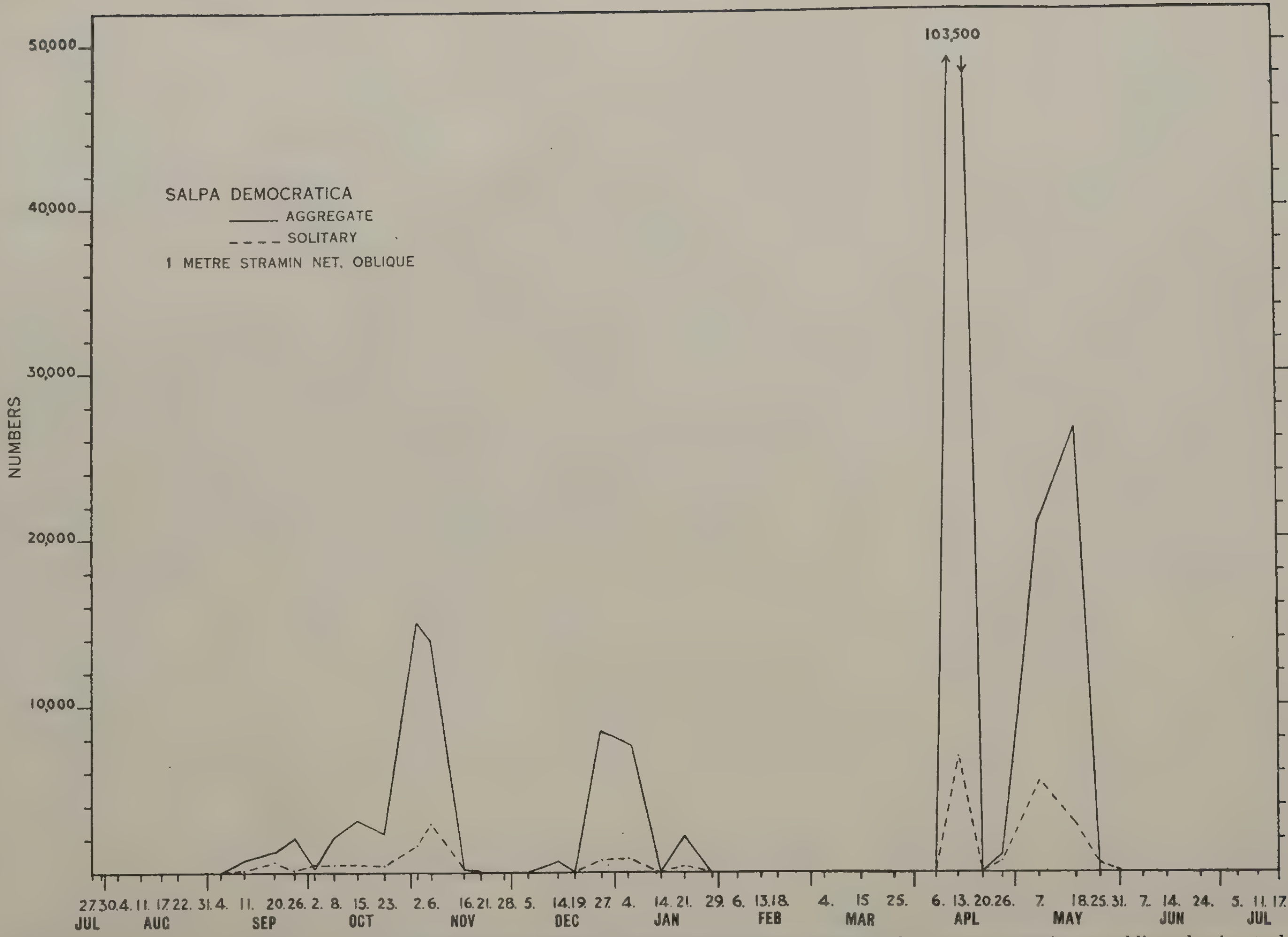
The most sudden increase was in April, 1929, when, after the occurrence of 12 and 22 Salps on 6th April (Station 52), the numbers taken on 13th April (Station 53) were 17,000 in the coarse silk net and 110,400 in the stramin net, the largest catch for the year. By 20th April (Station 54) there were only 17 and 50 Salps in the two nets respectively.

Before attempting to explain this seasonal distribution of *S. democratica*, it will be perhaps worth while to summarize briefly our knowledge of the life-history of this interesting animal.

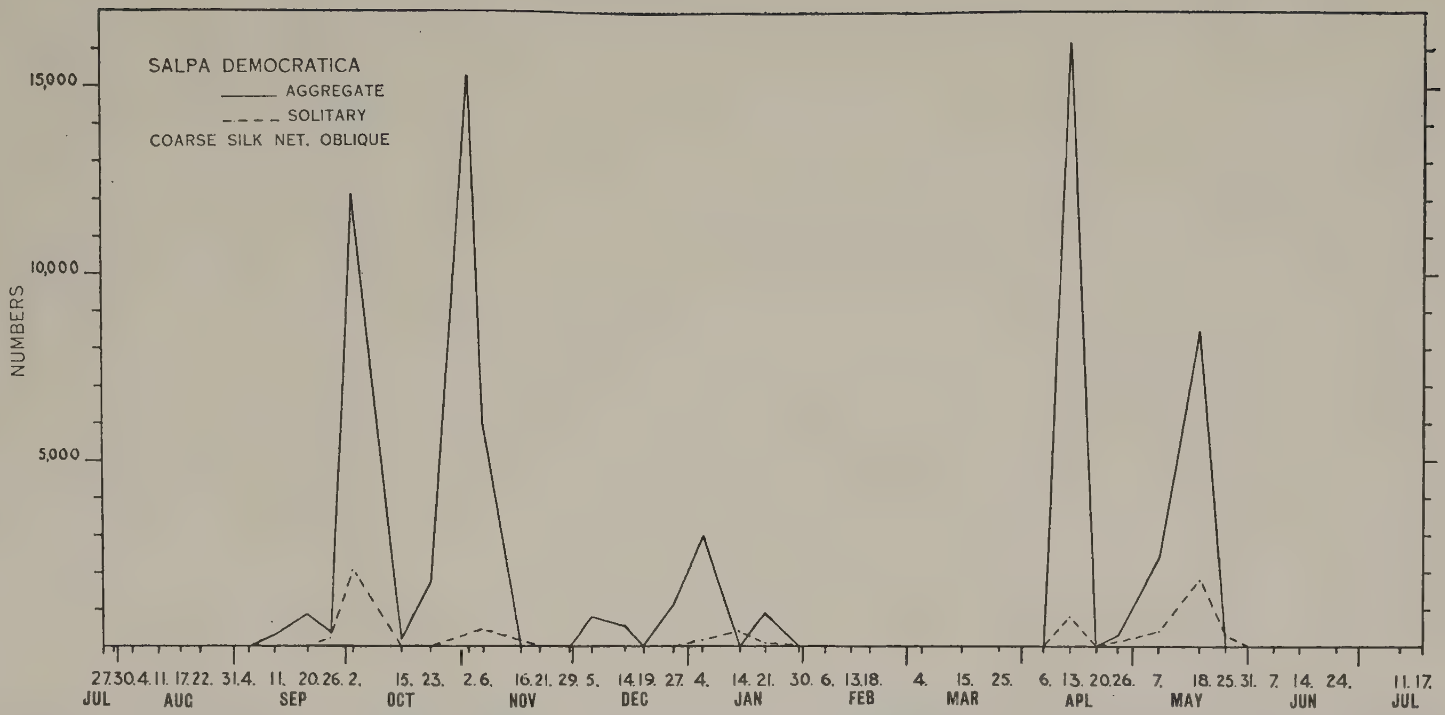
In common with other Salps, *S. democratica* goes through two generations in its complete life-cycle. The *solitary* individual produces offspring by budding from the stolon, and the buds when mature constitute the *aggregate* or *sexual* generation. Each individual of the aggregate generation produces sexually *one* of the solitary generation, although at first they carry three eggs, two of which disintegrate. Michael (1918, p. 244) says : " In *Salpa democratica* the stolon undergoes more or less regular periods of active segmentation and rest, so that the aggregate salpae are developed in sets or blocks, all individuals in a single block being of approximately the same size and in the same stage of development. Leuckart (1854, p. 67) found forty in one block and sixty-five in another ; while Seeliger (1886, p. 593) counted sixty-one in a single block. As there are from three to four blocks present when the distal end of the chain is ready to emerge from the mantle cavity to the exterior, the stolon carries in the neighbourhood of two hundred salpae at one time. No evidence is at hand that the stolon ever exhausts its capacity for producing them, and segmentation probably continues until terminated by the death of the solitary salpa."

Nothing is known as to the length of life or period required to attain maturity in the different forms.

In Text-fig. 6 we have made a complete summary of the seasonal abundance of total Salps in the stramin and coarse silk nets, inserting also the data as to temperature, salinity, and the phases of the moon. It is remarkable that in the earlier increases the peaks tend to be at about the period of full moon, while in the later increases the two peaks occur at or after new moon. Certain shore animals showed a similar periodicity in their breeding. On 23rd November, 1928, when proceeding to take a station outside Trinity Opening we passed through a great swarm of Salps just off the south-western corner of Batt Reef. No indication of this swarm was shown at the weekly station in the lagoon three miles east of Low Isles, either on 21st November (Station 27) or on 28th November (Station 30). We have indicated the position of this swarm with an asterisk in Text-fig. 6, and it is curious that this also occurs very near the full-moon period. It does not seem likely, however, that these increases really indicate a lunar periodicity in reproduction. While, from the method of reproduction of *S. democratica*, it is conceivable that considerable



TEXT-FIG. 4.—Curves showing the catches of aggregate and solitary forms of *Salpa democratica* in the 1-metre stramin net oblique hauls at the position 3 miles east of Low Isles in the barrier reef lagoon.



Text-fig. 5.—Curves showing the catches of aggregate and solitary forms of *Salpa democratica* in the coarse silk net oblique hauls at the position 3 miles east of Low Isles in the barrier reef lagoon.

numbers could be produced in a very short time, it seems extremely improbable that numbers so produced could so quickly die down to practically nothing.

It seems much more probable that, rather than indicating successive outbursts of reproduction in the waters round Low Isles, the sudden peaks of the curve are due to swarms drifting up the Barrier Reef lagoon. The occurrence of swarms of Salps, some of which cover very large areas, is well known, and various accounts of such swarms are collected together by Apstein (1894, pp. 53–64). If these are indeed swarms drifting past, it would be interesting to know how they have arisen, and why they appeared to be completely absent at certain times of the year.

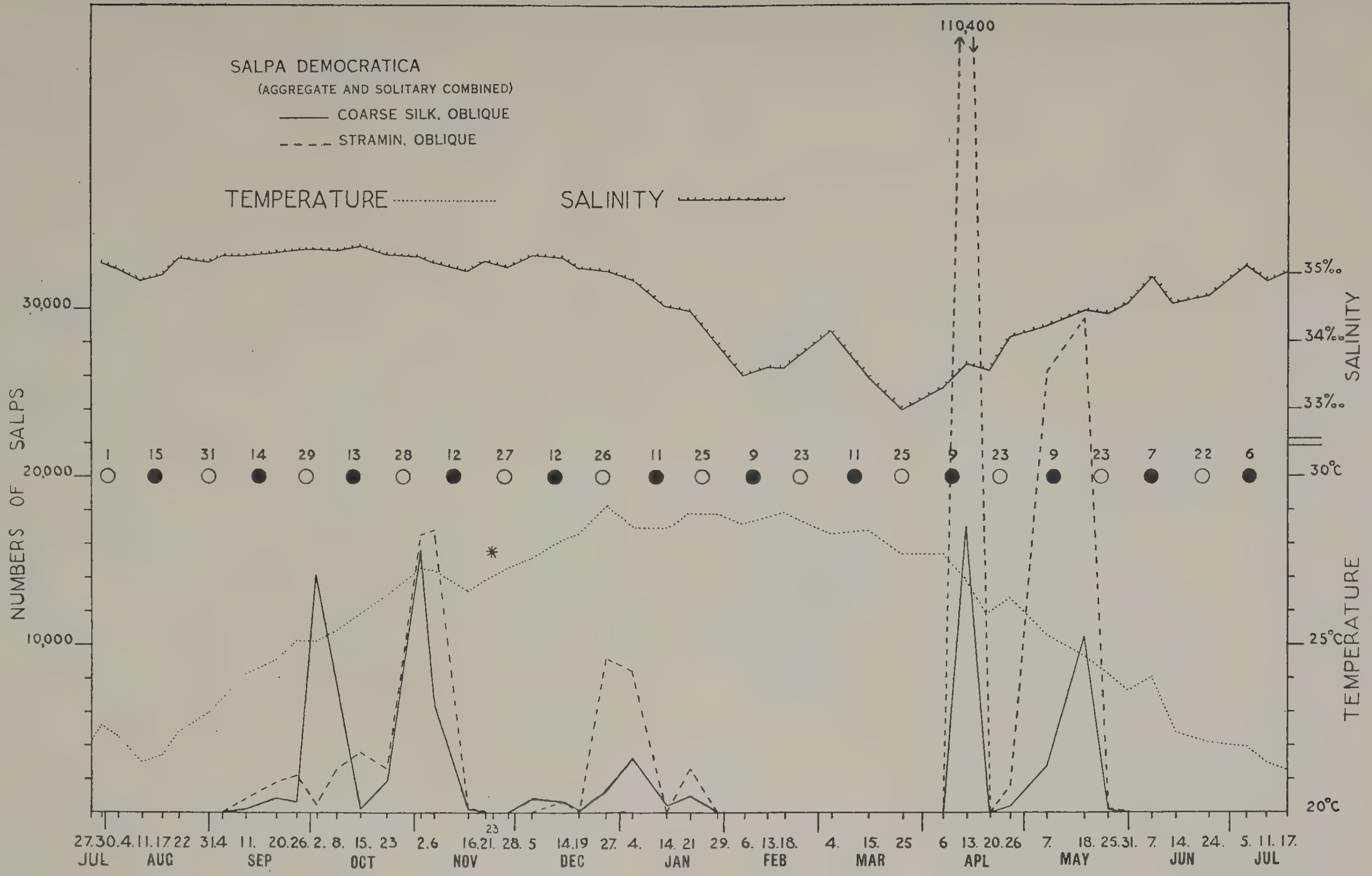
A comparison of their times of appearance with the hydrographic conditions (Text-fig. 6) shows that the two chief periods of abundance occurred when the temperature was rising from about 24° C. to 28° C. in September, October and November, and when it was falling from about 28° C. to 24° C. in April and May. There was also a smaller increase in December and January, when the temperatures lay between 27° C. and 28° C., and this was followed by a period of complete absence with the temperatures between 28° C. and 29° C., until April, when the temperatures were once more falling. Few Salps were taken with the temperature below 24° C. The period of almost complete absence in February and March coincided with the period of falling salinity, the lowest salinity of 33°/$_{\circ\circ}$ being reached in March, but the April increase took place before the salinity had risen much above 33·5°/$_{\circ\circ}$. While it is doubtful whether the salinity has any effect within the limits reached, it seems possible that the seasonal abundance of *S. democratica* may have been connected with the temperature of the water, especially as both the periods of greatest abundance occurred at about 24° C. to 28° C. This would indicate a definite periodicity in the reproduction of the Salps.

A definite seasonal distribution of *S. democratica* has been shown by Michael (1918, p. 250) in the waters off San Diego: "Both generations of this species occur on the surface mainly during the months of June and July, solitary forms being restricted entirely to these months. No collections, however, were made during the months of January, May, October or December." During this period of maximum abundance the average temperatures were 17·9° C. in June and 18·9° C. in July, the average salinities of 33·61°/$_{\circ\circ}$ and 33·64°/$_{\circ\circ}$ respectively. August was apparently the warmest month in the year, with an average temperature of 19·9° C.

The seasonal distribution of *S. democratica* in the Mediterranean at Naples has been given by Schmidtlein (1881, p. 164). This species is recorded as being present in January, February, March and May, and most abundant in July and then August. From figures given by Lo Bianco (1909, p. 533), the average temperatures in July and August are about 25·5° and 26°–27° C. respectively. In March the temperature may drop as low as 13° C.

Changes in seasonal abundance of Salps have also been recorded in such regions as the northern coasts of Scotland, where they are possibly not so much due to periodic reproduction as to passive carriage in the Atlantic Drift waters.

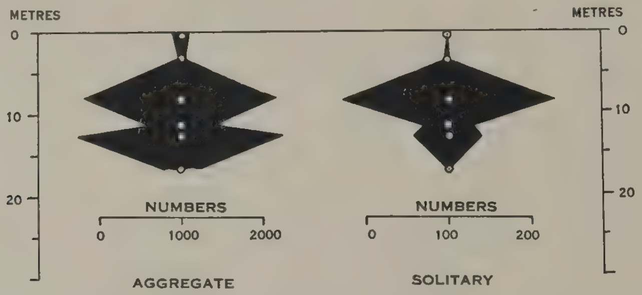
Presuming then that a seasonal distribution of *S. democratica* is shown by our Barrier Reef collections, are we to assume that the swarms producing the sudden increases off Low Isles are due to isolated centres of reproduction, or have they been brought about by other conditions? Apstein (1906, pp. 285 *et seq.*) discusses the possible methods of swarm production in Salps, and stresses what he calls the "self-purification of the currents" (Selbstreinigung des Strömes) as one of the causes in the open ocean. This effect occurs



Text-fig. 6.—Curves showing the catches of *Salpa democratica* (aggregate and solitary forms combined) in the 1-metre stramin and coarse silk nets, oblique hauls, at the position 3 miles east of Low Isles in the barrier reef lagoon. Curves are also given for the temperature and salinity, and the dates of full and new moons are shown.

on the edges of currents running through still regions, in counter currents, and where currents impinge upon one another or upon land. Such regions are comparable with those mentioned by Ruud (1932, p. 63). In contradistinction to these swarms there are those that appear seasonally at a certain place at the same time each year, such as those carried by the Atlantic Drift.

In examining the occurrence of the swarms in the barrier reef lagoon one cannot help being struck with the marked periodicity, which coincides more or less with the moon's phases. One wonders whether there may not be some tidal effects further to the south, or even in Trinity Opening, that allows swarms to be brought into the lagoon from the open ocean, or even whether they might not be carried over the tops of the outer barrier reefs at the spring tides. Examination of the hydrographic data shows, however, no indication that there is the slightest periodic change in the waters of the lagoon. We must therefore conclude that the swarms are indigenous to the lagoon, and it seems most probable that they are due to small centres of reproduction arising during the optimum breeding temperatures, the swarms thus produced drifting slowly northwards. Their coincidence with the moon's phases would then appear to be unexplainable until further observations have been made.



Text-fig. 7.—The vertical distribution of aggregate and solitary forms of *Salpa democratica* in the daylight in the barrier reef lagoon. Station 16 (3.x.28), 10.13 a.m. to 12.27 p.m. The circles and white dots indicate the average depths at which the hauls were made. Coarse silk townet. Secchi disc reading, 10 metres.

A periodicity in the occurrence of swarms of Salps has also been noticed by Seymour Sewell (1926) in the Indian Ocean. This he attempts to correlate with changes brought about by the periodic alteration from north-east to south-west in the direction of the winds during the monsoons, which set up seiches in the Andaman Sea and Bay of Bengal.

Vertical Distribution.—*Salpa democratica* only occurred at one of the stations made to study the vertical distribution of plankton in the barrier reef lagoon. Both the aggregate and solitary forms definitely avoided the surface layers in daylight. They reached their maximum abundance at about 10 metres and decreased rapidly in numbers below 15 metres. An indication of unevenness in horizontal distribution is given by the lower numbers taken at 11·1 m., this haul being taken after the remainder of the series had been completed. There is an indication from Text-fig. 7 that the solitary forms tend, if anything, to mass together at a slightly higher level than do the aggregate forms; see p. 217 (Michael, 1918). The actual numbers of individuals taken were as follows :

	Station **16.**	
	Aggregate.	Solitary.
S.	201	1
3·1 m.	60	5
8·0 ,,	2342	258
11·1 ,,	840	60
12·5 ,,	2485	83
16·5 ,,	420	2

ON THE PROPORTION OF SOLITARY TO AGGREGATE INDIVIDUALS IN THE SWARMS OF S. DEMOCRATICA.

Although the time taken to reach maturity is not known, attempts to calculate on any time basis the proportion of solitary to aggregate individuals likely to occur in nature soon show that when the varying circumstances of death-rate, time of individual breeding, length of life, etc., are taken into consideration no prediction can be made, except that on the whole one would expect the aggregate individuals to be usually the more numerous. Tables I and II show that the aggregate individuals were generally the more numerous in the Barrier Reef Expedition collections, but the actual proportions between the two types of individual vary rather widely, and are of the same order as in the catches of the same species given by Michael for San Diego (1918, pp. 246–248). It is, however, of interest to note that at the end of each of the two maximum periods of abundance in November and in May in the waters around Low Isles the solitary individuals preponderate. It is thus open to speculation whether this is an indication that the limiting factor in breeding operates on the individual that produces the eggs rather than on that in which the egg matures.

Owing to the even distribution of temperature from top to bottom in the waters of the barrier reef lagoon, it is unlikely that any differences in proportion between the two types of individuals could have been produced by differential behaviour, such as was observed by Michael (1918) off San Diego, where the solitary individuals tend to collect in the warmer surface waters.

Salpa zonaria (Pallas).

Only one specimen of *S. zonaria* was taken; this was in the bottom stramin net at Station 29 (24.xi.28) outside Trinity Opening, in about 200 metres of water, and was of the solitary form.

Salpa cylindrica, Cuvier.

S. cylindrica was not an abundant species in the collections, but occurred fairly frequently. Some specimens were taken in one or other of the nets in all months except July, October and June. The large catches at Station 35 (27.xii.28), Station 41 (13.ii.29), Station 52 (6.iv.29) and Station 55 (26.iv.29) in the stramin net (Table I) were due to the capture of chains of aggregate individuals; at Stations 41 and 52 there was only one solitary individual each, and at Station 55 there were 10, while at Station 35 solitary and free aggregate individuals were both present.

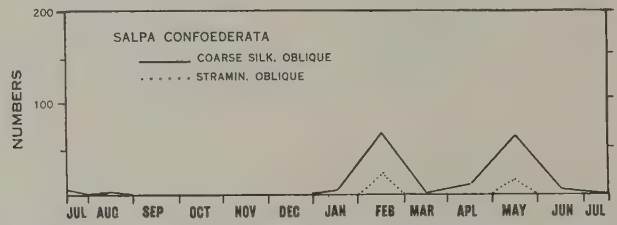
The solitary individuals of this species were apparently taken in greatest numbers just outside Papuan Pass at Station 50 on 18.iii.29.

On the whole *S. cylindrica* was most abundant between December and May at the weekly station.

Salpa confoederata, Forskål.

S. confoederata was, like *S. cylindrica*, not very abundant in our collections. It was entirely absent during the months from September to December inclusive, and in March, at the weekly station in the barrier reef lagoon. It appeared most abundantly at this station between January and June, and especially in February and May (Text-fig. 8). The largest catches consisted of 166 aggregate and 14 solitary individuals at Station 40 (6.ii.29) and 160 aggregate at Station 59 (31.v.29), both in the stramin net. The solitary individuals do not appear to have been so scarce as indicated by Metcalf (1918, p. 139), who suggests that they normally live deep in the water. Fourteen specimens of the aggregate form were caught at dredging Station XIV (7.iii.29, ½ mile S.E. of Lizard Island) in a hand net.

There was an indication that both this species and *S. cylindrica* appeared most abundantly at times when *S. democratica* was scarce.



Text-fig. 8.—Curves showing the average catch of *Salpa confoederata* for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. (Coarse silk and stramin nets, oblique hauls.)

Salpa rostrata, Traustedt.

Specimens of *S. rostrata* occurred in the collections of one net or another in November, December, January, April, May, June and July, but it was never abundant. The largest numbers were taken in December and in May. At the weekly station in the barrier reef lagoon every specimen identified was a solitary individual. One aggregate form, however, was taken at Station 19 (20.x.28) outside Trinity Opening. The absence of aggregate forms inside the Barrier Reef is rather remarkable. Ihle (1910, p. 29) records that the solitary form was taken at 10 stations on the Siboga Expedition, while the aggregate form was only caught at 3 stations.

Remarks on the Occurrence of Salps.

The geographical distribution of the Salps taken on the Great Barrier Reef Expedition is, according to Apstein (1906) and Seymour Sewell (1927):

C. pinnata: All three oceans; a purely tropical species which does not thrive in water below 20° C. In the Atlantic it is carried northward in the Gulf Stream.

S. democratica: Very common in the warm waters of all three oceans, and is carried north in the Atlantic Drift and south in the Brazil Current.

S. zonaria: In all three oceans; carried north in the Atlantic Drift.

S. cylindrica: Frequent in the tropical regions of all oceans.

S. confoederata: Found in the warmest parts of all three oceans. Metcalf (1918, p. 168) says that this is the most abundant species from collections in the region of the Philippine Islands.

S. rostrata: In tropical region of Atlantic Ocean and in the Indian Ocean. As a result of the Great Barrier Reef Expedition this species is now recorded in the Pacific. Its occurrence might, however, be expected, as it has been recorded by Ihle (1910, p. 29) from the region among the East Indies surveyed by the Siboga; Metcalf (1918, p. 166) records its absence from the Philippine region, but (1919, p. 4) expresses the opinion that it might be expected to occur.

These are all warm water species. Sewell (1926) divides the Indian Salps into two groups:

(A) Species whose solitary zooids normally inhabit deep waters, but occasionally come near the surface.

(B) Species whose solitary zooids normally inhabit the upper layers, but usually in Indian waters at some little depth below the surface.

Of the species taken on the Great Barrier Reef Expedition, *S. zonaria* and *S. confoederata* are included in (A) and the remainder in (B). The only individual of *S. zonaria* in our collections was taken in the bottom stramin net in water of about 200 metres.

If the Barrier Reef collections be compared with those of the Siboga Expedition the paucity of species is at once apparent. Ihle (1910) records 15 species of Salps from the Siboga catches, 3 *Cyclosalpa* spp., and 12 *Salpa* spp. In the region surveyed by the Siboga *S. democratica* (= *S. mucronata*) was also by far the most frequent Salp.

It seems possible that the paucity of species in our collections may indicate that the species caught are those better able to live in the conditions existing in shallow coastal waters, such as are found within the Barrier Reef. The same may also hold true for the small number of species of Appendicularians. On the other hand, it may be that in some years other species will be found to be present which, owing to their sparse distribution, happened not to be brought near the coast in the year we collected.

The absence of *S. fusiformis* Cuvier in our collections is perhaps surprising. It is recorded by the Challenger Expedition from north of New Guinea (Herdman, 1888, p. 75), and by Metcalf (1918) from the Philippine region. Ihle (1910) records it as fairly frequent from the region explored by the Siboga. It seems to be generally distributed in the Pacific Ocean, and Ritter (1905, p. 67) says that it is the most abundant species of *Salpa* of the western shores of North America, and probably of the whole Pacific, at any rate north of the equator.

In the region of San Diego Ritter (1905) only records 8 species of Salps.

APPENDICULARIA.

Eight species of Appendicularia were recorded: *Oikopleura rufescens*, Fol, *O. longicauda* (Vogt), *O. fusiformis*, Fol, *Megalocercus huxleyi* (Ritter and Byxbee), *Stegosoma magnum* (Langerhans), *Fritillaria haplostoma*, Fol, *F. pellucida*, Busch, and *F. borealis truncata* f. *intermedia*, Lohmann. In the stramin net catches *O. rufescens*, the most abundant species of all the Appendicularians, is the only *Oikopleura* sp. recorded. This is no doubt due to the large mesh of the stramin material, *O. rufescens* and the two large species *Megalocercus huxleyi* and *Stegosoma magnum* being the only Appendicularians which reach a large enough size to be retained. All species occurred at the weekly station in the barrier reef lagoon.

Family OIKOPLEURIDAE.

Genus *Oikopleura*, Mert.

Oikopleura rufescens, Fol.

O. rufescens was by far the most common and abundant species occurring in the Barrier Reef collections. This species was recorded for certain in 23 of the 46 coarse tow-net catches at the weekly station in the barrier reef lagoon, and it was probably present at all stations at which *Oikopleura* spp. were taken. In Table II are given the total figures for all *Oikopleura* spp. at each station, and the presence of the different species from the identifications of small samples is marked +. At Stations 27, 37, 39 and 41, in which *Oikopleura* spp. were especially abundant, the total number of each species is given in the proportions found in larger samples examined by Miss Hastings. These samples gave the following numbers :

Station **27** (21.xi.28). Coarse silk oblique :
145 *O. rufescens* (6 with horizontal rectum).
106 *O. longicauda*.
40 *Oikopleura* sp. (unfit for specific determination—both types, but more like *O. rufescens*).

Station **37** (14.i.29). Coarse silk oblique.
235 *O. rufescens* (23 with horizontal rectum).
37 *O. longicauda*.
66 *Oikopleura* sp. (unfit for specific determination—mainly *O. rufescens* type, but a few like *O. longicauda*).

Station **39** (30.i.29). Coarse silk oblique.
158 *O. rufescens* (19 with horizontal rectum).
6 *O. longicauda*.
87 *Oikopleura* sp. (unfit for specific determination—very nearly all of *O. rufescens* type).

Station **41** (13.ii.29). Coarse silk oblique.
204 *O. rufescens* (21 with horizontal rectum).
91 *O. longicauda*.
1 *O. fusiformis*.
56 *Oikopleura* sp. (unfit for specific determination—both kinds).

Measurements of a number of specimens were made by Miss Hastings, and we give below lengths, in millimetres, of trunk and tail, for the four largest individuals of those measured :

Station.	Date.	Trunk.	Tail.
2	30.vii.28	1·7	7·4
8	24.viii.28	1·7	6·8
22	23.x.28	1·9	5·2
55	26.iv.29	1·9	7·3

Details of the seasonal distribution are given on p. 225, where all the appendicularians are treated together.

Oikopleura longicauda (Vogt).

Next to *O. rufescens*, *O. longicauda* was the most abundant species in the coarse silk net catches at the weekly station. It was definitely recorded in 10 catches out of the 46 in which *Oikopleura* spp. occurred in the coarse silk tow-net oblique collections from this station. An examination of its numbers in the samples given above for Stations 27, 37, 39 and 41 seems to indicate that, while being much less numerous than *O. rufescens*, it was probably sufficiently abundant to have occurred in all the catches in which *Oikopleura* spp. were taken. It was not recorded as being found in the catches of the stramin net at any station, being, possibly, small enough to pass through the meshes.

Measurements of length of the larger individuals in mm. were as follows :

Station.	Date.	Trunk.	Tail.
3	4.viii.28	0·99	4·2
26	19.xi.28	0·7	3·4
27	21.xi.28	0·8	3·7
37	14.i.29	0·7	3·3
41	13.ii.29	0·6	2·8

Oikopleura fusiformis, Fol.

This species was definitely recorded at only two stations in the coarse net oblique catches, Station 14 (26.ix.28) and 41 (13.ii.29), and at Station 21 (22.x.28) in the stramin. The analysis of Station 41 given above shows that when present the numbers of *O. fusiformis* must have been very low, only one specimen being found out of 296 definitely identified specimens. It may be concluded therefore that throughout the year this species was easily the rarest of the three *Oikopleura* spp. occurring in our catches. That this was not due to small size is shown by the following measurements, which are comparable with those for *O. longicauda* :

Station.	Date.	Trunk.	Tail.
14	26.ix.28	0·75	3·8
21	22.x.28	1·1	3·7

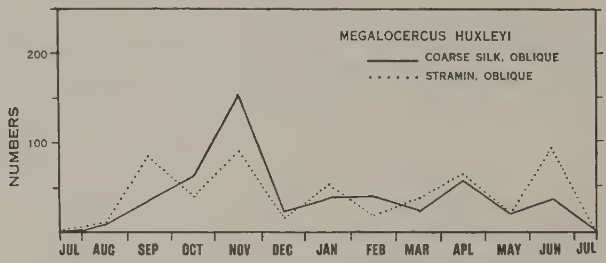
Genus *Megalocercus*, Chun.

Megalocercus huxleyi (Ritter and Byxbee).

Of the remaining Appendicularians *M. huxleyi* was the most commonly occurring, and on account of its large size was a striking object in the catches. In actual abundance it fell very far below *O. rufescens*, the largest catch for *M. huxleyi* being 380 specimens at

Station 24 (6.xi.28), and for *O. rufescens* 17,843 individuals at Station 37 (14.i.29), both in coarse silk net oblique hauls.

Tables I and II show that *M. huxleyi* occurred throughout the year at the weekly station, but was very rare in July. Text-fig. 9 gives the curves for the monthly averages of the catches of the oblique hauls with coarse silk and stramin nets. The curves show no really marked seasonal differences in distribution, but are on the whole very irregular. A closer examination of the figures for each catch for both nets shows that its numbers increased and decreased in a very irregular manner even during the period of a month. On the whole the sudden rises and falls agree very closely in the two nets, as shown in Text-fig. 10. There was, however, one station at which a very large catch in the coarse silk net was recorded when the stramin net catch was small, namely Station 30A (29.xi.28) [taken on the next day to stramin Station 30 (28.xi.28)]. The fact that these two stations were made on different days only stresses the spasmodic appearance of *M. huxleyi* and its evident tendency to swarm formation. While too much reliance should not, perhaps, be placed on the actual figures given in Tables I and II, owing to the method of sampling, we think that the agreements shown by the two nets, coupled with our own personal observations of the living catches (*M. huxleyi* being a striking animal when alive), confirm the general trend of the figures, and that the curves in Text-fig. 10 give a fairly true picture of the occurrence of *M. huxleyi* at the weekly station.

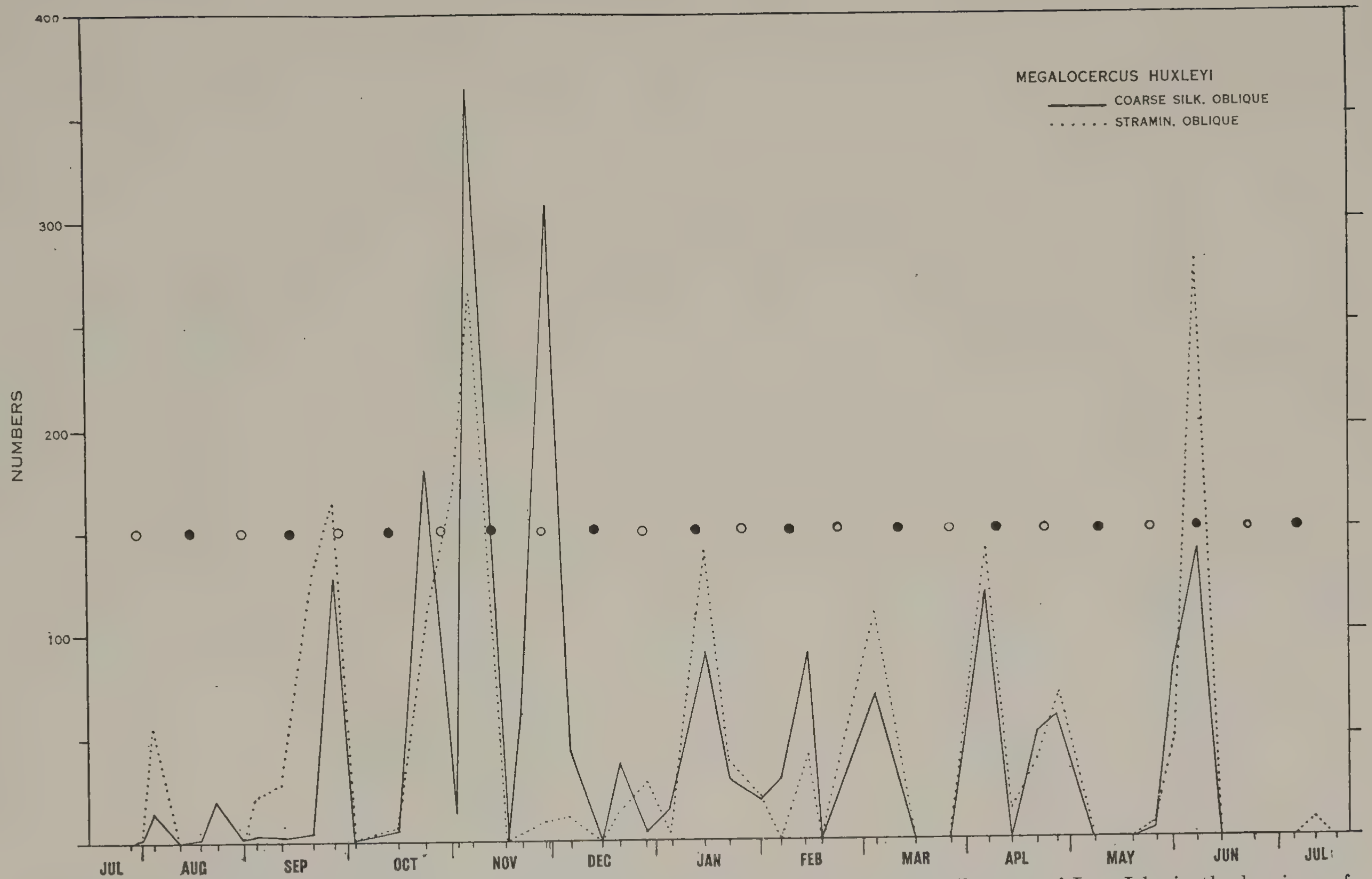


TEXT-FIG. 9.—Curves showing the average catch of *Megalocercus huxleyi* for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. (Coarse silk and stramin nets, oblique hauls.)

No obvious correlation could be found between the increase and decreases of this species and the weather conditions, hydrographical data, phases of the moon or transparency of the water; it must be concluded that the results shown are due to isolated swarms drifting up the barrier reef lagoon past Low Isles.

There was probably a tendency for the coarse silk net catches to hold a higher proportion of young individuals than the stramin net, as is indicated by the following figures given us by Miss Hastings. Here the "young" are regarded as those in which the gonads are not yet developed, or are only presented as rudiments, while in the "old" the gonads were instantly discernible :

			Young.	Old.
Station **39**	(30.i.29)	Coarse silk oblique	9	1 (gonads small).
		Stramin oblique	1	11 (2 disintegrating).
Station **41**	(13.ii.29)	Coarse silk oblique	18	29
		Stramin oblique	7	34 (4 disintegrating).



TEXT-FIG. 10.—Curves showing the actual catches of *Megalocercus huxleyi* at the position 3 miles east of Low Isles in the barrier reef lagoon. The dates of full and new moons are also shown. (Coarse silk and stramin nets, oblique hauls.)

Some measurements in mm. of the lengths of larger individuals of *M. huxleyi* were as follows :

Station.	Date.	Trunk.	Tail.
3	4.viii.28	3·7	12·6
10	4.ix.28	4·7	13·3
22	23.x.28	3·8	12·7
32	5.xii.28	4·0	11·7
50	18.iii.29	3·9	13·8
60	7.vi.29	4·4	13·4

M. huxleyi occurred abundantly in the oblique hauls at Station 8 (24.viii.28) and Station 26 (19.xi.28) in Trinity Opening, but curiously enough hardly occurred in the collections from outside the barrier, being taken only at Station 45 (28.ii.29) and Station 50 (18.iii.29), and then only in ones and twos. This may possibly have been because the hauls were deep vertical hauls, and did not fish for long in the upper water layers.

Genus *Stegosoma*, Chun.

Stegosoma magnum (Langerhans).

Tables I and II show that *S. magnum* was taken occasionally during most of the months of the year, but was apparently absent in May, June and July. In the stramin net catches at the weekly station in the barrier reef lagoon the largest number was 10, and the coarse silk net shows similar results. It is quite evident, then, that this species was much rarer than *M. huxleyi* in the barrier reef lagoon.

In Trinity Opening, however, *S. magnum* was quite abundant in two oblique catches, at Station 8 (24.viii.28) in the stramin net, and at Station 26 (19.xi.28) in the coarse silk net. The estimated numbers for these two catches were 160 and 169 respectively. As these are based on the actual identification of 56 and 25 individuals from the samples, they should be reliable.

Measurements of lengths of trunk and tail in mm. were as follows :

Station.	Date.	Trunk.	Tail.
3	4.viii.28	3·8	10·8
13	20.ix.28	(disintegrated)	9·3
22	23.x.28	2·3	8·7
26	19.xi.28	3·0	8·7
27	21.xi.28	2·9	5·2
37	14.i.29	3·1	7·7

(The anterior part of the head of *S. magnum* is usually rather shrivelled, and the measurements given are probably on the short side except those for Stations 3 and 26, which were made from specimens in excellent condition.)

Family Fritillaridae.

Genus *Fritillaria*, Q. and G.

Fritillaria haplostoma, Fol.

F. haplostoma was represented by only two individuals picked out from the fine silk net catch at Station 37 (14.i.29) in the barrier reef lagoon. It is possible that there may have been other specimens in the fine net collections, but owing to the shortage of time it was not possible to examine these catches as thoroughly as those of the stramin and coarse silk nets. From the size of its trunk (length in mm.) given below, however, it should have been retained in the coarse silk net catches if present.

Station.	Date.	Trunk (mm.).	Tail (mm.).
37	14.i.29	1·5	2·2

Fritillaria pellucida, Busch.

Only three specimens were identified, all from the fine silk net at Station 42 (18.ii.29), in the barrier reef lagoon.

Fritillaria borealis truncata f. *intermedia*, Lohmann.

One specimen only was identified, also from the fine silk net catch at Station 42 (18.ii.29), in the barrier reef lagoon, agreeing with Lohmann's definition (1931).

There were five other specimens of the *F. borealis* type from the same catch, but not in good enough condition for a more exact determination.

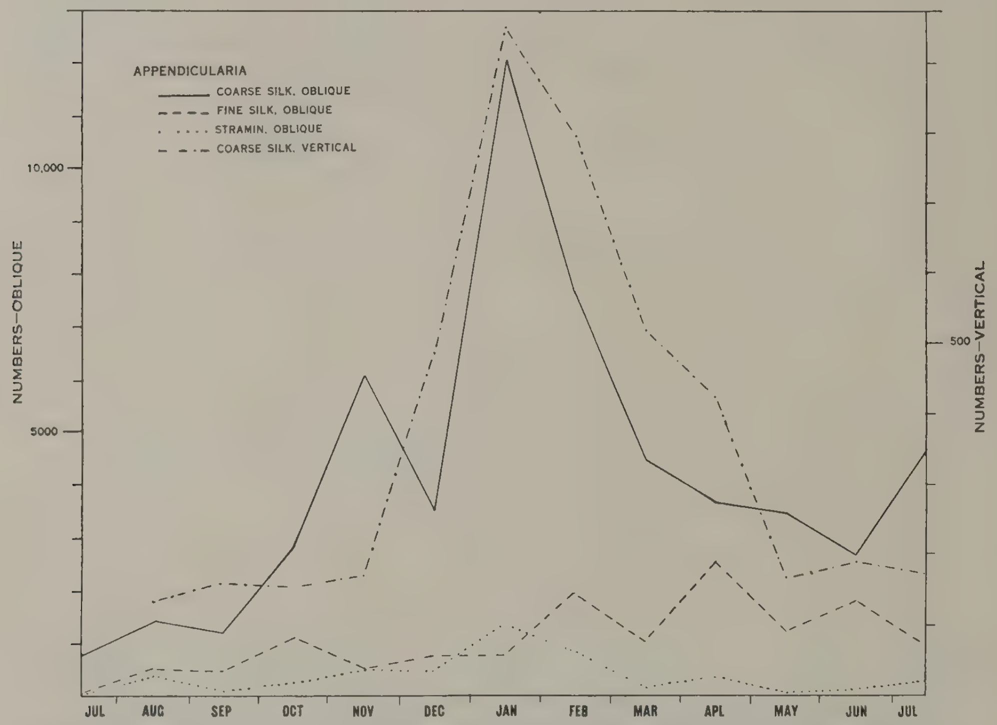
On the Occurrence and Seasonal Distribution of Appendicularians.

Since a complete numerical analysis has not been made of the different species of Appendicularians in the collections, it is advisable that in discussing their occurrence and seasonal distribution the group should be treated as a whole. Actually, owing to the comparatively small numbers of *M. huxleyi*, *S. magnum*, *O. fusiformis*, *F. haplostoma*, *F. pellucida* and *F. borealis*, the general results of the seasonal observations may be regarded as referring to *O. rufescens* and *O. longicauda* together, and especially to the former, which was undoubtedly the most abundant species.

Text-fig. 11 shows the curves for the average monthly occurrence of Appendicularians at the weekly station in the barrier reef lagoon. It indicates that in the coarse silk net oblique catches there was a gradual increase in numbers after September, when the monthly average was 1190, reaching a high maximum of 12,062 in January, with a slight drop in December. The numbers fell off rapidly in February and March to 4443, and from then onwards to July they were fairly steady, though rather higher than in the previous July, August and September. A careful examination of the results in Table II shows that, although there are considerable differences in the abundance from week to week, the monthly average curve may, on the whole, be regarded as giving a fairly true picture of the seasonal occurrence of appendicularians in the coarse silk tow-net catches.

The curve for the coarse silk net is followed closely by that for the stramin net, but in the latter the monthly averages are on the whole very much lower, being in September 200, and in January, 1318. It is probable that the majority of the smaller *Oikopleura* spp. individuals would pass through the meshes of the stramin net.

From a comparison of the two nets it appears possible that the monthly average for the coarse silk net oblique hauls in November may be unduly high owing to the very large catch made at Station 30A (29.xi.28). This collection was made on the day after the stramin net catch [Station 30 (28.xi.28)], in which appendicularians were rather low in number, and probably indicates the arrival of a swarm. The general trend of the seasonal distribution is confirmed by the vertical hauls with the coarse silk net (Text-fig. 11).



Text-fig. 11.—Curves showing the average catch of all Appendicularia for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. Owing to the preponderance of *Oikopleura rufescens* this curve probably holds good for this species. (Coarse and fine silk and stramin nets, oblique hauls; and coarse silk net, vertical hauls.)

The curve for the fine silk net, shown in Text-fig. 11, does not agree with those for the other two. Owing to the possibilities of clogging of the very fine silk during such long hauls, the results are of rather doubtful significance. It is probable, however, that the same species are represented in the catches, since an examination of a sample from fine net Station 55 (26.iv.29) by Miss Hastings gave 21 *O. rufescens* and 6 *O. longicauda*.

Ignoring the results of the fine silk net, the period of maximum abundance was January and February; this coincided with the period of highest temperatures, 28°–29° C., and of decreasing salinity.

As regards the geographical distribution of the species occurring in the Barrier Reef Expedition collections Lohmann (1931) gives the following:

O. rufescens: A true tropical form which is scarcer in the open ocean than in the coastal region; more frequent in the Indian Ocean than in the Atlantic.

O. longicauda: The characteristic species for the warm water region of all three oceans; abundant both in coastal waters and in the open ocean; sensitive to lowering of temperature, but can withstand low salinities.

O. fusiformis: Occurs generally in the warm water region of all three oceans, and is abundant both in coastal and ocean waters.

M. huxleyi: Occurs in Indian and Pacific Oceans, but has not been found in the Atlantic; in the Indian Ocean it occurs both in coastal and ocean waters. All its occurrences lie within a region where the surface water is more than 20° C.

S. magnum: A warm water form distributed in all three oceans, in coastal as well as ocean waters; occurs mostly in small numbers.

F. haplostoma: Distributed in the warm-water region of all three oceans, and is one of the most abundant *Fritillaria* species. Penetrates far into the coastal water, and appears, *viâ* the warm deep water, as a tropical visitor in Antarctic water.

F. pellucida: Occurs in the warm waters of all three oceans. It extends to 42° N. in the Atlantic, and as far south as 72° S. in the Weddell Sea.

F. borealis is cosmopolitan; it occurs in all three oceans and reaches from pole to pole. *F. borealis truncata* f. *intermedia* does not extend further south than about 40° S. (where it is abruptly replaced by *F. borealis acuta*). It is found throughout the Indian and Atlantic Oceans, in the Mediterranean Sea, and as far north as Davis Strait.

The paucity of *Fritillaria* spp. in the Barrier Reef collections, compared with those of the Siboga Expedition (Ihle, 1908), is at once evident. The Siboga Expedition records 7 species, *F. pellucida*, *F. haplostoma*, *F. formica*, *F. megachile*, *F. tenella*, *F. bicornis* and *F. borealis truncata* f. *ritteri*; of these only *F. pellucida* and *F. haplostoma* were found in the Barrier Reef collections, with the addition of *F. borealis truncata* f. *intermedia.* Each species was caught on one occasion only, in very small numbers, and all in the fine silk net. This scarcity may perhaps be explained to a certain extent by the fact that the collections made by the fine silk net have not been thoroughly examined, and by the possibility that in the coarse silk net catches the delicate *Fritillaria* spp. have been damaged beyond recognition by the bulk of the plankton. If, however, they had been abundant in the region, surely some would have been seen in the coarse silk net catches, and one cannot help feeling that their rarity is significant. Examination of the Siboga Expedition records shows the *Fritillaria* species were by no means common. *F. pellucida*, which was the most frequent species taken, appeared only at 17 stations out of the 69 at which Appendicularians were caught; *F. formica* and *F. borealis* f. *ritteri* were only taken at 8 stations; *F. tenella* at 5 stations, *F. bicornis* at 3, and *F. haplosoma* and *F. megachile* only at 1 station each. It is evident therefore that even *F. haplostoma*, which according to Lohmann is one of the most frequent of Fritillarians, was not abundant in the region surveyed by the Siboga Expedition.

Among the *Oikopleura* species Ihle (1908) records only 4 species from the Siboga Expedition, *O. longicauda*, *O. rufescens*, *O. fusiformis* and *O. cophocerca*, of which the first three occurred in the Barrier Reef collections. While, however, *O. rufescens* was easily the most abundant species in the Barrier Reef region surveyed, *O. longicauda* was the most frequent species taken by the Siboga Expedition, *O. rufescens* coming next in importance. This is perhaps in agreement with Lohmann's statement (1931) that *O. rufescens* is scarcer in the open ocean than in coastal waters, the Barrier Reef collections being purely coastal and shallow water, as opposed to many of the Siboga stations which were taken in deep water among the islands of the Dutch East Indies.

Of the true warm-water species of *Oikopleura*, *O. cophocerca*, *O. albicans*, *O. parva*, *O. intermedia*, *O. gracilis* and *O. cornuto-gastra* were absent from our collections. According to Lohmann, *O. intermedia*, though coastal and oceanic, has never been recorded from the Pacific, *O. gracilis* occurs only in the tropical region of the Indian Ocean, and *O. cornuto-gastra* has so far only been recorded from the Japanese coast. *O. cophocerca* and *O. albicans* thrive best in the open ocean far from the coast. *O. parva* is also a deep-water form that would hardly be expected to occur in our collections.

The absence of that cosmopolitan species *O. dioica* is, however, of especial interest, as the Siboga Expedition also failed to take it. It has been recorded elsewhere in the Pacific; on the western side by Aida (1907), off the Japanese coast, and by Lohmann (1931, p. 96) from the Bismarck Archipelago.

The two remaining species in our collections, *M. huxleyi* and *S. magnum*, appear to agree with the findings of other expeditions, the former being the more common. Ihle (1908, p. 106) says that in the region explored by the Siboga Expedition *M. huxleyi* was not rare, occurring in 44 stations out of the 69 at which Appendicularians were caught, but *S. magnum* was not frequent and never occurred in large numbers.

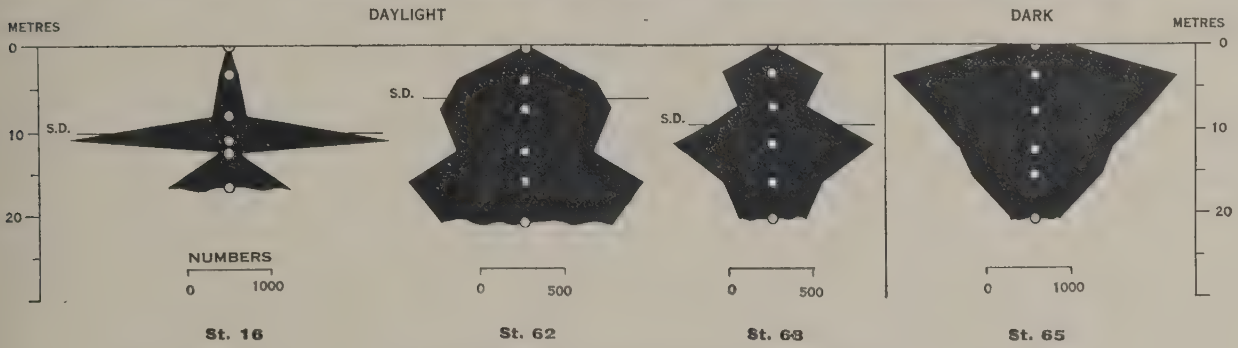
The only localities in the Pacific where seasonal observations have been made of Appendicularia are the Bismarck Archipelago (Lohmann, 1931, p. 96), San Diego off the Californian Coast (Essenberg, 1922), and the Japanese coast (Aida, 1907).

The Bismarck Archipelago collections were made by Dahl at Ralum down to depths of 500 metres during seven months in 1896–97. The collections were unfortunately not counted, and Lohmann (1931, p. 96) is only able to give the compositions of samples from the different catches in each month. The surface water ranged from 28–30° C. the whole time. The most abundant *Oikopleura* species was *O. longicauda*, which was followed by *O. fusiformis* and *O. rufescens* (Lohmann says *O. dioica*, but his Liste 30 shows *O. rufescens* to be more abundant). Among the Fritillaria species *F. borealis truncata* f. *ritteri* predominated, followed by *F. pellucida*, and somewhat further behind by *F. formica* and *F. haplostoma*. *S. magnum* was apparently more abundant than *M. huxleyi*. No conclusions as to seasonal abundance could be drawn, but examination of the numbers in the samples given in Liste 30 shows that most specimens and species occur in January, February and March.

For the Californian coast at San Diego we have more substantial data supplied by Essenberg (1922) as a result of daily collections from the pier head over a period of three years. Essenberg gives (1922, pp. 57 and 58) two curves showing the numbers of *Oikopleura* spp. and of *Fritillaria* spp. respectively, plotted against the temperature of the sea. "The greatest numbers of species and individuals occur in the cooler months from October to March and April. After that the animals decrease in numbers gradually, until in the summer months the *Fritillaria* almost completely disappear from the surface waters, and only the cosmopolitan species of *Oikopleura* such as *O. dioica* and *O. longicauda*, with rare exceptions of other species, occur in limited numbers in that season." "The optimum temperature lies between 14° and 16° C. At this temperature the maximum representation is reached. In a temperature above 16° a decrease of Appendicularians is noticed, and at 20°–22° they are almost completely absent from the surface waters."

In that region *O. dioica* is the most common species (Essenberg, 1926, p. 486), followed by *O. longicauda* and *O. fusiformis*. *O. cophocerca* and *O. rufescens*, among other species, have only been found occasionally. The Californian coast, being bathed by the cool south-going current, evidently has a more temperate appendicularian population than the western Pacific, and it seems possible that even in summer, with a temperature of 21° C., the water is only approaching the lower limit of the optimum temperature range of the warm-water species, or at any rate does not reach it for long enough to allow any species to establish itself abundantly.

Aida (1907) records *O. longicauda*, *O. dioica* and *O. fusiformis* as the commonest species off the coast of Japan, which agrees with the observations at San Diego. *O. rufescens* and *S. magnum* occur among the oceanic plankton organisms that approach the Japanese coast in mid-summer and early autumn. Aida (1907, p. 25) says, "It is in the summer, when that wind (south) prevails and the black current sweeps nearer the land than in other seasons, that the Copelata are most richly represented along the Pacific Coast of Japan".



TEXT-FIG. 12.—The vertical distribution of Appendicularians in the daylight and in the dark in the barrier reef lagoon. Station 16 (3.x.28), 10.13 a.m. to 12.27 p.m.; Station 62 (15.vi.29), 11.20 a.m. to 1.45 p.m.; Station 68 (18.vii.29), 10.30 a.m. to 12.55 p.m.; Station 65 (10.vii.29), 9.00 p.m. to 11.25 p.m. The circles and white dots indicate the average depths at which the hauls were made. Coarse silk townet. S.D., Secchi disc reading.

The Barrier Reef collections are so far the only records giving a full picture of a year's course in a region in the Pacific where warm tropical water conditions exist all the year round. In other seas we have the results of Lohmann at Messina in the Mediterranean, in the Weddell Sea, and off Kaiser Wilhelm II Land (1931), of Fish (1925), for the Woods Hole region in the Atlantic, and of Nikitin for the Black Sea, but none of these relate to regions strictly comparable with the Barrier Reef.

VERTICAL DISTRIBUTION.—The vertical distribution of appendicularians at the four stations taken in the barrier reef lagoon is shown in Text-fig. 12. While tending to avoid the actual surface layers, quantities of appendicularians occurred well above the bottom, so that the seasonal distribution shown by the oblique hauls should be reliable. At Station 16 there is an indication of considerable unevenness in horizontal distribution in that very large numbers were taken in the haul at 11·1 m., which was made after the rest of the series had been completed. The actual numbers caught at each station can be found in Table VIII, in Vol. II, No. 6.

At Station 65, which was taken in the dark, the appendicularians had evidently moved very much nearer the surface than they were in the daylight collections at the other three stations.

On the Occurrence of Appendicularian Houses.

Throughout the year the occurrence of the houses of appendicularians in the plankton was very noticeable, and they were often so abundant as to make counting of the smaller animals extremely difficult. As is to be expected, the abundance of the houses shows rather a similar course to that of the appendicularians themselves. They were definitely most abundant from November to February, the highest monthly average being 11,950 houses in the coarse net in January.

The presence of these slimy houses is evidently a very characteristic feature of some tropical waters, and their identification at first troubled the writers until the meshes of the grid could be made out. It is interesting to read in this connexion a description, evidently referring to these houses, given in the "Challenger" Reports (Summary of Results, p. 774), at Station 199 in the Celebes Sea: "There were also small masses of transparent jelly-like matter of various shapes, mostly spherical or cylindrical, containing inside small Diatoms like *Navicula*, Coccospheres, Rhabdospheres, and small Polycystinæ, and frequently attached to the outside the above-mentioned forms of Oscillatoriacea and other foreign bodies, including some Infusoria. These jelly or colloid masses rendered the townet quite sticky, as though covered with a coating of thin glue; they were generally about the size of peas . . ."

REFERENCES.

Aida, T. 1907. Appendicularia of Japanese Waters. J. Coll. Sci. Tokyo, XXIII, Art. 5, pp. 1–25, pls. i–iv.

Apstein, Carl. 1894. Die Thaliacea der Plankton-Expedition. B. Vertheilung der Salpen. Ergebn. Plankton-Exped. Humboldt-Stiftung, II, E.a.B., pp. 1–68, pls. ii–iv, 14 text illust.

—— 1906. Salpen der deutschen Tiefsee-Expedition. Wiss. Ergbn. "Valdivia" 1898–1899, XII, pp. 245–290, pls. xxvi–xxxii, 15 text illust.

Borgert, A. 1894. Die Thaliacea der Plankton-Expedition. C. Vertheilung der Doliolen. Ergebn. Plankton-Exped. Humboldt-Stiftung, II, E.a.C., pp. 1–68, pls. v–viii, 2 text-figs.

Essenberg, Christine E. 1922. The Seasonal Distribution of the Appendicularia in the Region of San Diego, California. Ecology, III, pp. 55–64, 3 text illust.

—— 1926. Copelata from the San Diego Region. Univ. Calif. Pub. Zool. XXVIII, pp. 399–521, 170 text illust.

Garstang, Walter. 1933. Report on the Tunicata. Part I: Doliolida. British Antarctic ("Terra Nova") Expedition, 1910. Natural History Report. British Mus. (Nat. Hist.) Zoology, IV, pp. 195–251, 8 text illust.

Herdman, William A. 1888. Report upon the Tunicata Collected during the Voyage of H.M.S. "Challenger" during the Years 1873–76. Rep. Sci. Res. "Challenger" Exped. Zool. XXVII, Part 76, pp. 1–166, pls. i–xi, 28 text illust.

Ihle, J. E. W. 1908. Die Appendicularien der Siboga-Expedition. Siboga Exped., Monog. LVI c, pp. 1–123, pls. i–iv, 10 text illust.

—— 1910. Die Thaliaceen (einschliesslich Pyrosomen) der Siboga Expedition. Siboga Exped., Monog. LVI d, pp. 1–55, pl. i, 6 text illust.

LO BIANCO, SALVATORE. 1909. Notizie biologiche riguardanti specialmente il periodo di maturità sessuale degli animali del golfo di Napoli. Mitt. Zool. Stat. Neapel, XIX, pp. 513–761.

LOHMANN, H. 1931. Die Appendicularien der Deutschen Tiefsee-Expedition. Wiss. Ergebn. " Valdivia " 1898–1899, XXI, pp. 1–158, pls. i–v, 18 text illust.

METCALF, MAYNARD M., and BELL, MARY M. 1918. The Salpidæ: A Taxonomic Study. Bull. U.S. Nat. Mus. 100, II, pp. 5–193, pls. i–xiv, 150 text illust.

METCALF, MAYNARD M. 1919. The Salpidæ Collected by the United States Fisheries Steamer " Albatross " in Philippine Waters during the Years 1908 and 1909. Bull. U.S. Nat. Mus. 100, II, pp. 1–4.

MICHAEL, ELLIS L. 1918. Differentials in Behavior of the Two Generations of *Salpa democratica* Relative to the Temperature of the Sea. Univ. Calif. Pub. Zool. XVIII, pp. 239–298, pls. ix–xi, 1 text illust.

NEUMANN, GÜNTHER. 1906. Doliolum. Wiss. Ergebn. " Valdivia " 1898–1899, XII, pp. 93–243, pls. xi–xxv, 20 text illust.

RITTER, WM. E. 1905. The Pelagic Tunicata of the San Diego Region, excepting the Larvacea. Univ. Calif. Pub. Zool. II, pp. 51–112, pls. ii, iii, 31 text illust.

RUUD, JOHAN T. 1932. On the biology of Southern Euphausiidae. Hvalrådets Skrifter. Scientific Results of Marine Biological Research. No. 2, pp. 1–105, 37 text illust.

SCHMIDTLEIN, RICHARD. 1880. Vergleichende Übersicht über das Erscheinen grösserer pelagischer Thiere und Bemerkungen über Fortpflanzungsverhältnisse einiger Seethiere im Aquarium. Mitt. Zool. Stat. Neapel. II, pp. 162–175.

SEYMOUR SEWELL, R. B. 1926. The Salps of Indian Seas. Rec. Ind. Museum, XXVIII, pp. 65–126, 43 text illust.

TABLE I.—*Tunicata Occurring in Oblique Hauls of the* 1-*metre Stramin Net at the Stations in the Barrier Reef Lagoon* 3 *miles East of Low Isles.*

Station number.	Date.	*Salpa democratica.*		*Salpa confœderata.*		*Salpa cylindrica.*	*Salpa rostrata.*	*Cyclosalpa pinnata* (aggregate).	*Doliolum tritonis.*	*Doliolum denticulatum.*	*Doliolum* spp.	*Megalocercus huxleyi.*	*Stegosoma magnum.*	*Oikopleura rufescens.*	*Oikopleura* spp.
		Solitary	Aggregate	Solitary	Aggregate										
1	27.vii.28	..	..	..	..	..	..	..	..	1	..	..	..	10	..
2	30.vii.28	1	..	..	4	..	..	1	..	14	..	1	..	184	45
3	4.viii.28	..	..	..	1	1†	..	..	..	10	..	56	7	1518	2236
5	11.viii.28	..	..	..	..	..	..	..	..	9	..	..	..	..	..
6	17.viii.28	..	..	..	..	..	..	..	..	106	..	1	..	103	24
7	22.viii.28	89	53	..	..	..	..	..	..	112	..	..	1	..	11
9	31.viii.28	63	..	..	..	..	..	..	..	26	..	..	..	..	..
10	4.ix.28	9	25	..	..	..	..	..	..	8	..	22	..	..	101
12	11.ix.28	99	704	..	..	..	..	..	..	26	..	27	2	90	..
13	20.ix.28	572	1174	..	..	3	..	..	..	17	..	130	8	..	..
14	26.ix.28	131	2080	..	..	..	..	..	..	11	..	163	4	250	..
15	2.x.28	364	120	..	..	..	..	..	..	81	..	2	..	..	..
18	15.x.28	498	3092	..	..	..	..	..	..	12	..	7	..	261	..
22	23.x.28	233	2310	..	..	..	..	..	..	2	..	107	2	576	..
23	2.xi.28	1611	14,924	..	..	..	..	..	..	12	..	172	..	..	..
24	6.xi.28	2920	13,920	..	..	..	..	..	..	20	..	265	..	..	804
25	16.xi.28	120	90	..	..	..	..	..	..	..	..	..	..	..	..
27	21.xi.28	10	..	..	..	..	1	..	..	..	..	4	9	1015	120
30	28.xi.28	..	..	..	..	..	..	..	..	23	4	10	3	280	..
32	5.xii.28	11	10	..	..	..	..	..	128	746	16	12	4	84	..
33	14.xii.28	..	600	..	..	..	..	..	..	..	..	..	..	..	610
34	19.xii.28	..	50	..	..	10†	4	..	..	10	10	14	2	910	..
35	27.xii.28	745	8171	..	..	178†	58	..	122	13	49	28	7	113	..
36	4.i.29	810	7610	..	..	..	..	..	56	14	..	3	..	607	..
37	14.i.29	58	..	..	..	..	1	..	..	..	3	140	..	2260	..
38	21.i.29	360	2230	..	..	..	2	..	..	..	..	40	..	820	..
39	30.i.29	10	20	..	8	..	..	..	..	10	..	20	..	1380	..
40	6.ii.29	10	10	14	166	..	..	..	..	2	..	..	..	192	128
41	13.ii.29	..	..	11	12	155*	..	..	..	1	..	41	..	1700	29
42	18.ii.29	3	10	..	..	2	..	..	..	..	71	..	..	..	440
47	4.iii.29	..	..	..	..	1	..	..	..	38	29	110	10	380	..
48	15.iii.29	..	..	..	..	..	..	..	..	9	..	..	..	..	..
51	25.iii.29	11	..	..	..	..	..	..	..	..	..	..	..	..	1
52	6.iv.29	1	21	..	..	195*	..	..	..	60	..	140	10	265	15
53	13.iv.29	6900	103,500	8	11	..	..	..	..	160	..	15	..	..	..
54	20.iv.29	40	10	..	..	..	..	..	..	27	..	38	..	170	..
55	26.iv.29	500	1050	..	20	100*	..	..	..	3	..	70	..	580	..
56	7.v.29	5400	20,800	1	50	1†	..	..	..	120	..	..	..	..	..
57	18.v.29	2800	26,600	7	40	3†	3	..	..	60	..	..	..	..	..
58	25.v.29	110	20	1	..	..	90	..	..	7	..	6	..	60	..
59	31.v.29	2	..	..	160	..	10	..	..	7	6	50	..	..	..
60	7.vi.29	..	2	..	2	..	..	..	..	147	13	280	..	70	..
61	14.vi.29	..	..	..	5	..	..	..	..	2	..	..	..	..	..
63	24.vi.29	..	..	..	1	..	..	..	..	2	..	..	..	..	..
64	5.vii.29	..	..	..	..	..	1	..	..	60	..	..	..	..	700
66	11.vii.29	..	..	..	1	..	..	..	..	1	..	10	..	..	..
67	17.vii.29	..	..	..	..	..	..	..	..	15	..	..	..	..	20

* Some of the aggregate individuals were still united as chains, though free from the parent. The component individuals of these chains have been counted, and the number given comprises them as well as the completely free aggregate individuals. St. 41 also contains 1 solitary; St. 52, 1 solitary; and St. 55, 10 solitary.

† St. 3, solitary; St. 34, aggregate and solitary; St. 35, 7 solitary; St. 56, 1 solitary; St. 57, 3 solitary.

TABLE II.—*Tunicata Occurring in Oblique Hauls of the Coarse Silk Tow-net at the Stations in the Barrier Reef Lagoon 3 miles East of Low Isles.*

Station number.	Date.	*Salpa democratica.*		*Salpa confœderata.*		*Salpa cylindrica.*		*Salpa rostrata.*	*Doliolum gegenbauri.*	*Doliolum tritonis.*	*Doliolum denticulatum.*	*Doliolum* spp.	*Megalocercus huxleyi.*	*Stegosoma magnum.*	*Oikopleura fusiformis.*	*Oikopleura longicauda.*	*Oikopleura rufescens.*	*Oikopleura* spp.
		Solitary	Aggregate	Solitary	Aggregate	Solitary	Aggregate											
1	27.vii.28	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	+	440
2	30.vii.28	..	..	..	..	..	..	..	..	..	..	10	1	..	..	..	+	1142
3	4.viii.28	3	..	..	..	1	5	..	..	..	2	..	15	2	..	+	+	2652
5	11.viii.28	..	..	..	..	..	..	..	..	..	3	..	..	..	..	..	+	1810
6	17.viii.28	..	..	..	..	..	..	..	..	..	45	..	1	..	..	..	+	989
7	22.viii.28	3	..	..	..	..	..	..	..	..	415	..	20	3	..	+	+	1420
9	31.viii.28	3	..	..	..	..	..	..	..	..	8	..	1	..	..	..	..	..
10	4.ix.28	..	10	..	..	..	..	..	..	..	1	..	3	..	..	..	+	1430
12	11.ix.28	13	270	..	..	..	..	..	..	..	10	..	2	..	..	..	..	429
13	20.ix.28	29	892	..	..	..	..	..	..	..	3	..	4	4	..	..	+	840
14	26.ix.28	241	378	..	..	..	..	..	..	..	2	..	127	6	+	+	+	1920
15	2.x.28	2103	12,151	..	..	..	..	..	..	..	329	..	1	..	..	..	+	2200
18	15.x.28	38	220	..	..	..	..	..	..	..	2	..	6	..	..	..	+	5057
22	23.x.28	60	1750	..	..	..	..	..	..	1	2	..	180	120	..	..	+	923
23	2.xi.28	340	15,311	..	..	2	9	..	..	..	..	..	14	..	..	..	..	10
24	6.xi.28	480	5960	..	..	12	..	..	..	..	2	..	380	..	..	..	..	611
25	16.xi.28	152	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
27	21.xi.28	..	..	..	..	..	..	..	..	..	..	..	62	123	..	6530	8939	2466
30A	29.xi.28	..	..	..	..	..	..	..	..	..	..	..	307	..	..	+	+	10,810
32	5.xii.28	10	800	..	..	..	..	1	..	7	44	..	44	..	..	..	+	3210
33	14.xii.28	10	612	..	..	..	..	..	..	..	..	..	..	..	..	..	+	1200
34	19.xii.28	..	..	..	..	..	2	10	130	10	13	1400	37	..	..	+	+	4110
35	27.xii.28	1	1110	..	..	3	3	..	..	50	..	204	4	8	..	..	..	5440
36	4.i.29	183	3037	..	..	1	..	2	..	..	231	..	15	..	..	..	?	2420
37	14.i.29	410	..	..	..	..	..	..	..	..	..	412	90	10	..	2810	17,843	5447
38	21.i.29	78	890	..	..	..	..	..	..	..	..	..	30	..	..	..	+	5970
39	30.i.29	..	20	..	..	..	..	..	..	..	621	..	20	..	..	316	8330	4934
40	6.ii.29	..	..	..	60	..	..	..	..	..	10	..	30	..	..	..	..	3570
41	13.ii.29	..	..	..	2	..	..	..	..	..	3	10	90	..	41	3710	8318	2641
42	18.ii.29	..	20	..	..	..	..	..	..	..	..	235	..	..	..	..	..	4550
47	4.iii.29	..	..	..	..	..	..	..	+	..	173	60	70	..	..	+	+	11,130
48	15.iii.29	..	..	..	..	..	..	..	..	..	11	..	..	..	..	..	..	400
51	25.iii.29	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..	1800
52	6.iv.29	2	10	..	..	..	..	..	..	65	196	..	120	..	..	..	+	7880
53	13.iv.29	800	16,200	1	..	1	..	1	..	..	593	130	..	..	..	..	..	400
54	20.iv.29	17	..	..	..	..	..	..	..	..	30	..	50	..	..	..	+	3014
55	26.iv.29	80	330	..	..	..	..	10	..	..	31	..	60	..	..	..	+	3140
56	7.v.29	400	2400	1	..	1	..	1	..	..	724	..	..	..	..	..	+	2200
57	18.v.29	1800	8600	3	41	..	..	..	..	..	70	..	..	..	..	..	..	600
58	25.v.29	210	..	1	..	1	..	80	..	..	..	1	5	..	..	..	..	6060
59	31.v.29	31	..	..	..	..	..	10	..	..	..	..	80	..	..	..	+	4820
60	7.vi.29	12	1	..	..	..	..	1	..	..	302	17	140	..	..	..	+	2280
61	14.vi.29	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	2000
63	24.vi.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3410
66	11.vii.29	..	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	3600
67	17.vii.29	..	..	..	..	..	..	..	..	..	23	..	..	..	..	..	+	5431

+ Implies that the species was noted as present but not counted in the sample.

TABLE III.—*Tunicata from Stations other than that 3 miles East of Low Isles.*

Station number.	Date.	Position.	*Salpa democratica.*		*Salpa confœderata.*		*Salpa cylindrica.*		*Salpa rostrata.*	*Salpa zonaria.*	*Cyclosalpa pinnata.*	*Doliolum tritonis.*	*Doliolum denticulatum.*	*Doliolum* spp.	*Megalocercus huxleyi.*	*Stegosoma magnum.*	*Oikopleura fusiformis.*	*Oikopleura longicauda.*	*Oikopleura rufescens.*	*Oikopleura* spp.
			Solitary	Aggregate	Solitary	Aggregate	Solitary	Aggregate												
								COARSE SILK NET.												
8	24.viii.28	I.T.O.	2	1	..	..	1	..	..	..	..	..	..	..	72	4	..	..	+	155
11	6.ix.28	I.T.O.	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..	..	..	400
19	20 .x.28	O.T.O.	28	5	..	..	..	..	1	..	..	44	46	..	..	..	..	..	..	5
20	20.x.28	O.T.O.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	300
21	22.x.28	3 m. E. night	285	1765	..	..	..	..	..	..	..	..	24	..	+	+	..	..	..	2850
26	19.xi.28	I.T.O.	1	..	..	..	..	..	..	..	..	..	1	..	..	169	..	130	1636	254
28	23.xi.28	O.T.O.	10	..	..	..	..	..	..	..	..	..	10	5	..	..	..	..	..	102
43	26.ii.29	C.B.	..	..	..	1	1	..	..	..	..	..	..	10	..	..	..	..	..	600
44	27.ii.29	Li.I.	1	..	..	..	..	..	..	..	..	..	30	..	23	..	..	..	..	1590
45	28.ii.29	O.C.P.	..	..	..	..	..	..	..	..	..	..	221	44	2	..	..	..	..	400
46	28.ii.29	I.C.P.	..	..	1	..	..	..	..	..	..	..	..	10	23	..	..	..	..	1030
49	17.iii.29	I.P.P.	11	61	..	..	2	..	..	..	..	..	80	60	50	..	..	+	+	3420
50	18.iii.29	O.P.P.	..	325	..	..	8	..	..	..	..	..	3	8	..	..	..	..	..	405
								STRAMIN NET.												
8	24.viii.28	I.T.O.	4	124	..	..	..	..	..	..	..	..	..	..	230	160	..	..	45	..
11	6.ix.28	I.T.O.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	20.x.28	O.T.O.	12	27	..	..	..	..	..	..	1	12	20	..	3	3	..	..	..	..
21	22.x.28	3 m. E. night	627	3081	..	..	..	..	..	..	..	..	..	..	240	..	+	..	+	82
26	19.xi.28	I.T.O.	1	..	..	..	..	..	..	..	..	..	2	..	..	30	..	..	2100	160
28	23.xi.28	O.T.O.	33	..	..	..	..	..	..	..	..	..	5	8	..	..	..	..	..	30
29	24.xi.28	O.T.O. B.S.N.	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
31	2.xii.28	3 m. E. B.S.N.	10	10	..	..	..	..	..	..	..	..	..	..	3	..	..	..	100	..
43	26.ii.29	C.B.	..	..	2	..	..	3	..	..	..	..	..	10	1	..	..	..	..	41
44	27.ii.29	L.I.	2	..	..	..	..	..	..	..	..	4	10	10	2	1	..	..	200	..
45	28.ii.29	O.C.P.	2	3	..	..	..	..	..	..	..	..	10	8	1	..	..	..	..	..
46	28.ii.29	I.C.P.	9	..	..	..	1	1	..	..	..	8	8	15	95	..	..	..	110	..
49	17.iii.29	I.P.P.	110	441	..	..	5	10	..	..	..	..	90	80	140	30	..	..	180	..
50 (i)	18.iii.29	O.P.P.	2	110	..	..	78	62	..	..	..	..	54	28	1	..	..	..	..	..
50 (ii)	18.iii.29	O.P.P.	13	131	4	4	78	..	..	..	3	..	4	26	1	..	..	..	..	..

I.T.O., in Trinity Opening; O.T.O., outside Trinity Opening; C.B., off Cape Bedford; Li.I., off Lizard Island; O.C.P., outside Cook's Passage; I.C.P., inside Cook's Passage; I.P.P., inside Papuan Pass; O.P.P., outside Papuan Pass; B.S.N., bottom stramin net. St. 50 (i) = 400 m. St. 50 (ii) = 170 m. (For positions see Chart II, Vol. II, No. 1.)

+ Implies that the species was noted as present but not counted in the sample.

MOLLUSCA

Molluscs did not form a very important part of the plankton population at any time of the year, the average catches for the whole year being, for the stramin net 2·2% of the total catch, for the coarse silk net oblique hauls 3·0%, and for the fine silk net 3·8%. The highest values reached in any one month for these nets were respectively 6·7%, 4·9% and 8·9% (this excludes fine silk Station 25 (16.xi.28), when a catch of 114,500 lamellibranch larvae was recorded. This was evidently a swarm, perhaps of newly spatted larvae, and its presence was not indicated by the coarse silk net, which was fishing at the same time).

We give below the average catch for each month expressed as a percentage of the total animals caught for each net :

Number of Molluscs as Percentage of Total Animals Caught in each Month.

	Oblique hauls.		
	Stramin.	Coarse silk.	Fine silk.
1928 :			
July	1·1	2·4	..
August	1·0	4·2	0·2
September	1·2	3·9	3·5
October	2·7	4·9	8·9
November	1·3	3·6	3·0 (or 44·4)*
December	1·3	2·2	3·6
1929 :			
January	5·4	2·1	7·6
February	6·5	2·5	4·0
March	6·7	3·4	5·7
April	0·9	3·4	4·6
May	1·3	2·3	3·7
June	2·3	3·4	3·8
July	0·4	2·5	0·7
Average for year (based on average catch for each month)	2·2	3·0	3·8

The mollusca were represented by planktonic pteropods and heteropods, and the temporary larval stages of gastropods and lamellibranchs. In addition there were one or two isolated specimens of young cephalopods caught.

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* Including Station 25 (16.xi.28).

Below is given the percentage composition of the average monthly catches of mollusca in the oblique hauls with the stramin and coarse silk nets :

Percentage Composition of Average Monthly Catches of Mollusca.

	Oblique hauls.							
	Stramin.				Coarse silk.			
	Pteropods.	Heteropods.	Gastropods.	Lamellibranchs.	Pteropods.	Heteropods.	Gastropods.	Lamellibranchs.
1928 :								
July	91·1	8·9	..	..	1·5	0·7	42·9	54·9
August	59·5	27·5	13·0	..	0·8	0·8	49·6	48·8
September	76·0	24·0	..	..	1·6	2·6	61·9	33·9
October	71·8	28·2	..	..	19·4	..	54·9	25·7
November	51·3	35·9	12·8	..	51·8	0·4	39·0	8·7
December	30·5	6·7	62·8	..	57·5	..	32·7	9·8
1929 :								
January	96·9	2·8	0·3	..	64·3	0·4	15·3	20·0
February	83·2	15·6	1·2	..	29·8	0·4	29·8	40·0
March	90·0	7·4	2·6	..	26·7	..	22·3	51·0
April	75·2	17·8	7·0	..	30·5	0·4	38·0	31·1
May	57·4	33·3	9·3	..	24·2	1·1	31·1	43·6
June	57·3	38·5	4·2	..	18·2	1·3	29·3	51·2
July	41·7	58·3	..	..	0·8	..	11·5	87·7
Average for year (based on average catch for each month)	66·4	15·1	18·5	..	24·7	0·5	36·0	38·8

On the average for the year, 66·4% of all mollusca in the stramin net catches were pteropods. Of the remainder, 15·1% were heteropods and 18·5% gastropod larvae ; the high percentage of gastropod larvae is, however, due to one large catch at Station 35 in December. The large size of the stramin mesh allowed no lamellibranch larvae to be retained. In the coarse silk net the larval molluscs played a much greater part, comprising on the average 74·8% of the total molluscs, 36·0% being gastropods and 38·8% lamellibranchs. Of the remainder in the coarse silk net 24·7% were pteropods, while only 0·5% were heteropods. An examination of the figures for each month shows also that in the coarse silk net it was only from October, 1928, to June, 1929, that the pteropods were of importance, in the remaining three months the molluscs being almost entirely larval gastropods and lamellibranchs.

GASTROPODA.

PTEROPODA.

The Pteropods have been identified by the late Miss Anne L. Massy, of the Fisheries Department, Dublin. Fifteen species were recorded, of which 13 were Thecosomatous and 2 Gymnosomatous. They were *Peraclis* sp., *Cavolinia longirostris* (Les.), *C. tridentata*

(Forsk.), *C. inflexa* (Les.), *C. uncinata* (Rang.), *C. quadridentata* (Les.), *Diacria trispinosa* (Les.), *Cleodora pyramidata* (L.), *Creseis* (*Hyalocylix*) *striata* (Rang.), *Creseis* (*Styliola*) *subula* (Q. and G.), *Creseis virgula*, Rang., *C. acicula*, Rang., *Gleba* sp. ? *Pneumoderma mediterraneum*, Van Beneden, and *Paraclione pelseneeri*, Tesch.

Creseis virgula, *C. acicula* and *Cavolinia longirostris* were the only common species at the weekly station in the barrier reef lagoon, and at other stations within the barrier. The only other pteropods occurring at all within the barrier were one specimen of *Cavolinia tridentata* recorded at Station 15 (2.x.28), and single specimens of *Paraclione pelseneeri* taken in the stramin and coarse silk nets, oblique hauls, at Station 6 (17.viii.28). One *Pneumoderma mediterraneum* was recorded from the anchorage of Low Isles on April 2nd, 1929.

The collections from outside the barrier were much richer in species, 13 different species being taken as shown in Tables IV, V and VI.

A separate report has not been published by Miss Massy, but in the following accounts of the species the passages in inverted commas have been taken verbatim from her manuscript.

EUTHECOSOMATA.

Family Limacinidae.

Genus *Peraclis*, Forbes.

Only one limacinid pteropod has been found in all the plankton catches taken during the Great Barrier Reef Expedition. This occurred at Station 20 (20.x.28) outside Trinity Opening, and belonged to the deep-water genus *Peraclis*. The specimen was sent to Prof. Tesch for identification, but was not in a fit state of preservation for him to say definitely which species it was ; he thought, however, that possibly it was *P. reticulata*, d'Orbigny.

Limacinids might conceivably have been overlooked among the numerous gastropod larvae in the plankton. All the gastropod larvae picked out from the collections have, however, been re-examined by Prof. Pelseneer and one of us (F. S. R.), but not a single pteropod could be found among them except the *Peraclis* mentioned above.

Family Cavoliniidae.

Genus *Cavolinia*, Gioeni, 1873, Abildgaard 1791.

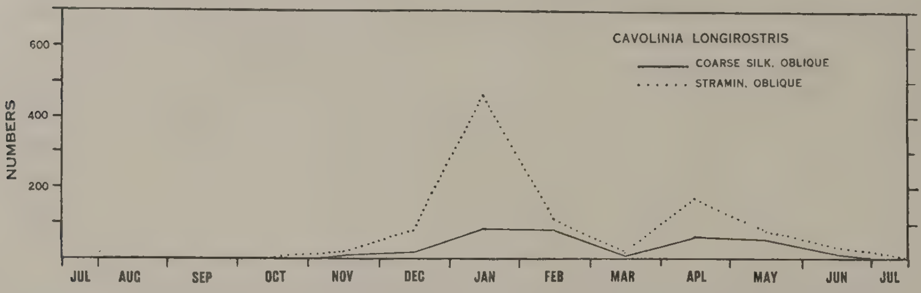
Cavolinia longirostris (Lesueur), 1821.

Cavolinia longirostris was by far the commonest species of this genus and, next to *Creseis acicula* and *Creseis virgula*, the most abundant pteropod within the barrier. At the weekly station in the barrier reef lagoon single specimens only were taken from July to October, but an increase in abundance started in November which reached a maximum in January, when the largest catch of 1216 individuals was made in the stramin net at Station 38 (21.i.29). The numbers fell again very low in March, but rose to a fresh peak in April, when the largest catch was 435 in the stramin net at Station 53 (13.iv.29). Thereafter the numbers fell once more to a minimum in July. Text-fig. 13 shows graphically the average monthly catches for this species in the stramin and in the coarse silk nets, oblique hauls. The coarse silk net catches reflect those of the stramin net, but owing to the larger amount of water filtered by the stramin net the catches for that net are the greater. This indicates that the majority of the *C. longirostris* taken were of a large size and would not pass through the meshes of the stramin.

At Station 27 (21.xi.28) the specimens were "mostly young." The presence of two "larvae" is recorded from Station 50 (18.iii.29) outside Papuan Pass.

"In almost all the specimens the shells were beautifully preserved, so that it was a pleasure to sort them." Immediately after sorting from the formalin-preserved collections the pteropods were placed in 70% alcohol.

This species occurred both inside and outside the barrier.



TEXT-FIG. 13.—Curves showing the average catch of *Cavolinia longirostris* for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. (Coarse silk and stramin nets, oblique hauls.)

DISTRIBUTION.—"In Atlantic up to about 47° N. latitude. Indian and Chinese Seas very abundant." Tesch (1906) records this species as very abundantly distributed in the whole region surveyed by the Siboga Expedition and "certainly the most common species of *Cavolinia* in the East Indian Archipelago".

Cavolinia tridentata (Forsk.), 1775.

C. tridentata was never recorded from the plankton, but only at Dredge Station XV (8.iii.29, ½ mile outside Cook's Passage, 210 fathoms), when one whole specimen and one empty shell were taken.

"Distributed in all warm seas." Tesch (1904) reports it as "not so abundant as nearly all the other species of *Cavolinia*" in the Siboga collections.

Cavolinia inflexa (Les.), 1812.

C. inflexa was only taken at two stations outside Trinity Opening, namely Station 19 (20.x.28), stramin net, one specimen; metre silk net, "? three young", and Station 28 (23.xi.28), stramin net, one; coarse net, four. It was never recorded from any locality within the barrier.

"Distributed in all warm seas. Wanders occasionally with a warm current as far as about 50° N. off the south west of Ireland." From the Siboga collections Tesch records it as not nearly so abundant as *C. longirostris*.

Cavolinia uncinata (Rang.), 1836.

C. uncinata was never recorded from the plankton, but only from Dredge Station XV (8.iii.29), when one shell was taken.

" Distributed in all warm seas." This species was very common in the Siboga collections (Tesch 1904), but the specimens were chiefly empty shells.

Cavolinia quadridentata (Les.), 1821.

Like *C. inflexa*, *C. quadridentata* was only recorded from outside Trinity Opening at Station 19 (20.x.28), 6 specimens in stramin net, and at Station 29 (24.xi.28), when one " shell " was taken in a depth of about 205 metres in the bottom stramin net.

" Distributed in all warm seas." Recorded by Tesch (1904) as a very common form in the whole area of Siboga Expedition.

Genus *Diacria*, Gray, 1842.

Diacria trispinosa (Les.), 1821.

D. trispinosa was never recorded from the plankton, but only from Dredge Station XV (8.iii.29), when one shell was taken in the dredge.

" Distributed in all warm seas. Wanders occasionally with a warm current as far as about 50° N. off the South-west of Ireland." Of this species Tesch (1904) remarks that on the Siboga Expedition not a single living animal was obtained, but only empty shells. He comments upon this, as several authors say that the species is very abundant in warm seas.

Genus *Cleodora*, Péron and Les., 1810.

Cleodora pyramidata (L.), 1767.

C. pyramidata was only recorded from outside Trinity Opening; at Station 28 (23.xi.28) stramin net, five; coarse net, one, and at Station 29 (24.xi.28) when " ? three shells " were taken in the bottom stramin net at about 205 m. Also from Dredge Station XV (8.iii.29) Miss Massy records " ? two broken shells ".

" Widely distributed in warm and temperate seas." Under the name of *Clio pyramidata* Tesch records this species as found at many stations on the Siboga Expedition, and by far the most common form among the species of Clio.

Genus *Creseis*.

Subgenus *Hyalocylix*, Fol, 1875.

Creseis (*Hyalocylix*) *striata* (Rang), 1828.

H. striata was recorded only at six stations. During the months of October, November and December it occurred in small numbers both outside Trinity Opening and at the weekly station in the barrier reef lagoon from the stramin net.

" Widely distributed in all warm seas." In the Siboga material Tesch (1904) records this species as very abundant at some stations, and occurring throughout the whole region explored.

Subgenus *Styliola*, Les., 1825.

Creseis (*Styliola*) *subula* (Q. and G.), 1827.

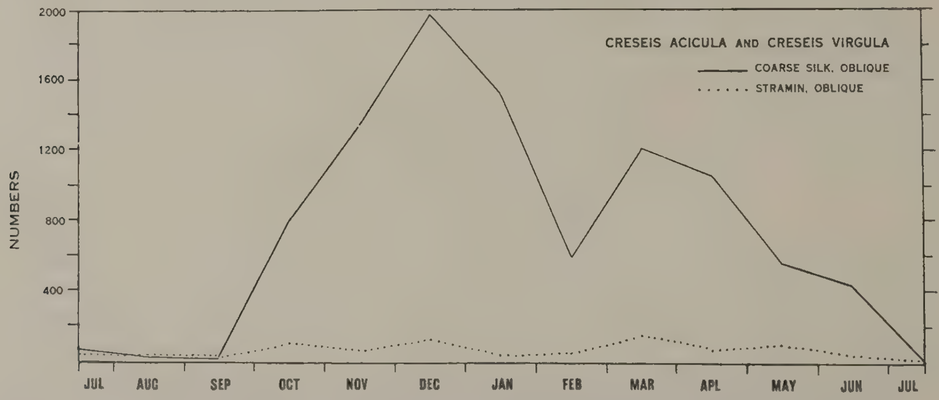
This species was only recorded from Station 19 (20.x.28), Station 28 (23.xi.28), and Station 29 (24.xi.28). At Station 29 " two and two shells " were recorded from the bottom stramin net in about 205 metres.

" This is a warm-water species, but it appears to avoid the immediate neighbourhood of the equator." Tesch (1904) recorded that it did not appear to be very abundant from the Siboga Expedition.

Subgenus *Creseis*, Rang, 1828.

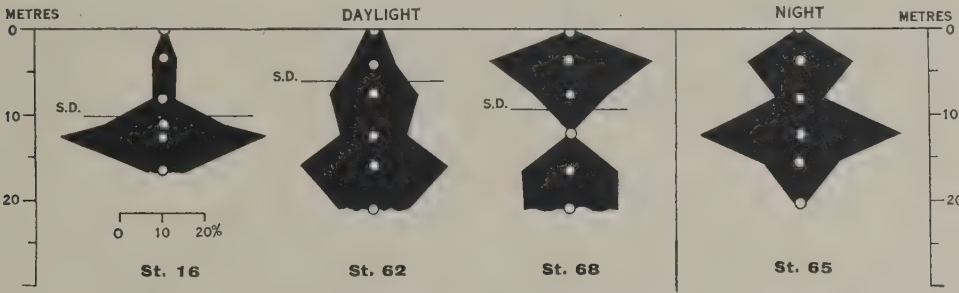
Creseis virgula, Rang, 1828, and *Creseis acicula*, Rang, 1828.

C. virgula and *C. acicula* will be discussed together since they were by far the most abundant pteropods in our catches. They were found both inside and outside the barrier. When sorting the material these two species were placed together as " *Creseis* sp." and it is not possible to apportion the numbers between them for certain. In Table IV an attempt has been made to apportion the numbers between the two species at certain stations from numbers supplied by Miss Massy, and it would appear that when present *C. virgula* was the most numerous. *C. acicula*, however, seemed to be numerically most important from July to November, and again from April to July. In fact no specimens of *C. virgula* were recorded by Miss Massy from our sorted samples for July and August. Thus it appears that of the two species, both of which had a marked seasonal change in abundance, *C. acicula* had a more prolonged season. In Text-fig. 14 are given the average monthly catches for both species together, for the coarse silk and the stramin nets, oblique hauls. It appears that the period of greatest abundance was from October to June ;



TEXT-FIG. 14.—Curves showing the average catch of *Creseis acicula* and *Creseis virgula* combined, for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. (Coarse silk and stramin nets, oblique hauls.)

this may probably be taken as correct for *C. acicula*, but for *C. virgula* it should possibly be November to April. The curve for the coarse silk net shows that the two species together rose to a maximum of abundance in December when the average monthly catch was 1977 specimens ; they then fell away to a low number in February, rising to a second peak in March, when the monthly average was 1217 ; they then gradually fell once more to a minimum in July. Text-fig. 14 also indicates that, unlike *Cavolinia longirostris*, *Creseis* spp. were caught in greatest numbers by the coarse net. This is a proof that the majority of *C. acicula* and *C. virgula* taken during the months of October to June were very small, and passed through the meshes of the stramin net. It was only in July, August and September that the stramin and coarse silk net catches were about equal. For instance in July, August and September the average monthly catches were for the stramin net 48, 40 and 27 individuals respectively, and for the coarse silk net 63, 33 and 28 ; but in December, while the average for the stramin net was only 119, that for the coarse silk net was 1977. The largest catch was made in the coarse silk net at Station 33 (13.xii.28), when 4215 specimens were recorded.



TEXT-FIG. 15.—The vertical distribution of Creseids, probably mostly *Creseis acicula*, in the daylight and in the dark in the barrier reef lagoon. Station 16 (3.x.28), 10.13 a.m. to 12.27 p.m. ; Station 62 (15.vi.29), 11.20 a.m. to 1.45 p.m. ; Station 68 (18.vii.29), 10.30 a.m. to 12.55 p.m. ; Station 65 (10.vii.29), 9.00 p.m. to 11.25 p.m. The circles and white dots indicate the average depths at which the hauls were made. Coarse silk townet. S.D., Secchi disc reading. The diagrams are expressed as percentages. At Stations 65 and 68 the numbers were rather low.

These two species " occur in all warm seas ". Tesch (1904) says that in the region of the Siboga Expedition *C. virgula* and *C. acicula* were by far the most common forms, and that *C. acicula* was perhaps the more abundant. Our results indicate that *C. acicula* was probably the more constant rather than the more abundant in the Barrier Reef region.

VERTICAL DISTRIBUTION.—In Text-fig. 15 are shown the vertical distribution diagrams for Creseids at the four stations taken in the barrier reef lagoon (see Table VI). These stations were made at seasons when *Creseis acicula* was the more abundant of the two species. These pteropods, which avoid the surface layers in the daylight, show a significant rise towards the surface between Station 16 and Station 62 in relation to the transparency of the water, the Secchi disc readings being 10 m. and 6 m. at these two stations respectively. The numbers caught at Stations 65 and 68 were perhaps rather too low to give a good picture of the vertical distribution. From the diagrams it can be safely assumed that the seasonal distribution as shown by the oblique hauls has not been seriously affected by changes in the vertical distribution of these species.

At Station 16 the two species have been sorted with the following results :

	C. acicula.	*C. virgula.*
S.	..	..
3·1 m.	7	11
8·0 ,,	13	4
11·1 ,,	89	1
12·5 ,,	145	2
16·5 ,,	39	..

These figures indicate that probably *C. virgula* lives much nearer the surface in the daytime than does *C. acicula*. In Text-fig. 15 the two species have been combined, but *C. virgula* is present in such small numbers as only to cause a slight thickening of the diagram at 3·1 m.

Family CYMBULIDAE.

Genus *Gleba*, Forsk., 1774.

Gleba sp.

One specimen of an undetermined species of *Gleba* was taken in the vertical haul with the stramin net at Station 19 (20.x.28), outside Trinity Opening. Of this specimen Miss Massy says : " This is in poor condition and measures but 6 mm. by 4 mm. across the fins, but nevertheless it shows distinctly the characteristic indentations on the lateral margins of the fins. Each lappet has a number of close-set curved muscles crossing another set which radiate towards the centre of the fin. The latter show only a set of slightly undulating muscles which run side by side from the anterior to the posterior margin. The margins are transparent and without muscles. There is no trace of a shell."

GYMNOSOMATA.

Family PNEUMODERMATIDAE.

Genus *Pneumoderma*, Cuvier, 1804.

Pneumoderma mediterraneum, Van Beneden, 1838.

One specimen only was caught in the Low Isles anchorage on 2nd April, 1929.

" This measures about 6 mm. in length. It is in poor condition and of a dirty yellow colour with white translucent dots, and some very dark pigment is sparingly distributed in narrow lines, when viewed microscopically. The specimen is somewhat contracted, only one sucker-bearing appendage being partly visible. Both appendages have 6–8 suckers of three sizes. The radula appeared to have at least 4 or 5 lateral teeth on each side. The hooks are of equal length and in golden tube-shaped sheaths. A lateral gill and quadrangular posterior gill are present. In appearance this specimen strongly resembles Tesch's figure (1904) of *Pn. pygmaeum*, which, however, only measured 3 mm., and in which the radula was not examined. In the present specimen the largest suckers seemed to be in the middle, but owing to the contracted state of the little creature, it is difficult to be certain."

" Atlantic, Mediterranean, Indian and Chinese seas." No specimens of this species were recorded by Tesch (1904) from the Siboga collections.

Genus *Paraclione*, Tesch, 1904.

Paraclione pelseneeri, Tesch, 1904.

P. pelseneeri occurred only at Station 6 (17.viii.28) at the weekly station in the barrier reef lagoon, where the stramin and the coarse silk nets each contained one specimen.

"These both measure but 3·50 mm. in length. They have a transparent skin and cream-coloured viscera, and in each the organs adhere closely to the left wall, and there is a large transparent mass of branched connective tissue. Neither specimen shows any dark chromatophores. The narrow tail-like posterior end of the body occupies more than a quarter and less than a third of the length. It is throughout quite too narrow to contain any viscera, but is ringed closely by muscle bands. Two bands of muscles cross on the fins, forming a delicate lattice work which stops short of the margin. Both specimens arrest the attention at a glance by a peculiar long white fold which proceeds on either side from the lateral posterior portion of the anterior lobes of the foot. At first I believed that these folds constituted the sides of a long posterior lobe to the foot, and that the specimen might therefore prove to be the yellow *Clione flavescens*, Gegenbaur, = *Clione aurantiaca*, Fol., which is described by Gegenbaur as having a long posterior lobe to the foot. By holding the specimens at different angles and examining them with various magnifications, however, I convinced myself that there was no posterior lobe to the foot visible and that these folds formed the base of the fin.

"They are somewhat as shown in Tesch, 1904, Pl. VII, figs. 148 and 149 of *P. pelseneeri*. The buccal bulb of one specimen was examined, and proved to have two pairs of buccal cones, and a radula (2—1—2) and hooks corresponding fairly well with Tesch's (*l. c.*) Pl. VI, figs. 151 A and B. The hooks are all of the same length, and not bent. The median tooth appears to have a central cusp, but it is difficult to be certain of this, or whether there may be more than two lateral rows owing to its minute size. There is also present a rudimentary jaw somewhat like that shown by Mme. Pruvot-Fol (1924), fig. xiv ép., for *Clionina longicaudata* Soul."

Hitherto only taken from three stations in the East Indian Archipelago by Tesch (1904), who described it from the Siboga Expedition material.

ON THE OCCURRENCE OF PTEROPODS.

While the pteropods as a group have been widely recorded by a few of the larger oceanographic expeditions, there appears to have been no detailed study of their occurrence throughout the season, or of their life-histories in any one locality in warm regions. The results of the Great Barrier Reef Expedition must therefore be regarded as the first contribution towards a seasonal study of this group in the tropics.

It is quite evident that in the coastal waters of the Barrier Reef region only three species were of importance in the year under review, namely *Creseis virgula*, *C. acicula* and *Cavolinia longirostris*. Whether the same three species would predominate every year we cannot say, but judging from the results of the Siboga Expedition (Tesch, 1904) in the East Indian Archipelago region, where these same three species were also the most common, it seems probable that their occurrence is normal. Prof. Pelseneer has told us that Creseids are forms which extend normally nearer the coasts than other genera.

It is perhaps surprising that there is a complete absence of Limacinids except for the solitary *Peraclis* taken at Station 20 (20.x.28) outside Trinity Opening. This specimen was taken in a vertical haul from 250 m., and Tesch (1910) says, " More than any other genus of the Thecosomata, *Peraclis* seems to belong to the mesoplankton." The absence of this genus, at any rate from the shallow coastal waters, is not so surprising.

As regards the pteropods as a whole Tesch found, from the results of the Percy Sladen Trust Expedition (1910), that in the Indian Ocean *Creseis virgula*, *Hyalocylix striata* and *Cavolinia longirostris* were the only species caught in the daytime at the surface. This possibly also accounts for the small number of specimens taken in coastal waters. In the waters outside the barrier more species might have been expected, but the hauls were undoubtedly too few to gather a representative collection of the rarer species. The majority of species are rather sparsely distributed, and only met with occasionally in net collections.

HETEROPODA.

The only common Heteropod recorded from the collections was *Atlanta peroni*, Lesueur, which occurred both inside and outside the barrier. It was present throughout the year at the weekly station in the barrier reef lagoon.

Two other species were found : *Firoloida kowalewskii*, Vayssière, was taken in small numbers at the weekly station and outside Trinity Opening, and *Pterotrachea* (*Euryops*) *mutabilis* Tesch was taken once at the weekly station in the barrier reef lagoon.

Family Atlantidae.

Genus *Atlanta*, Lesueur, 1817.

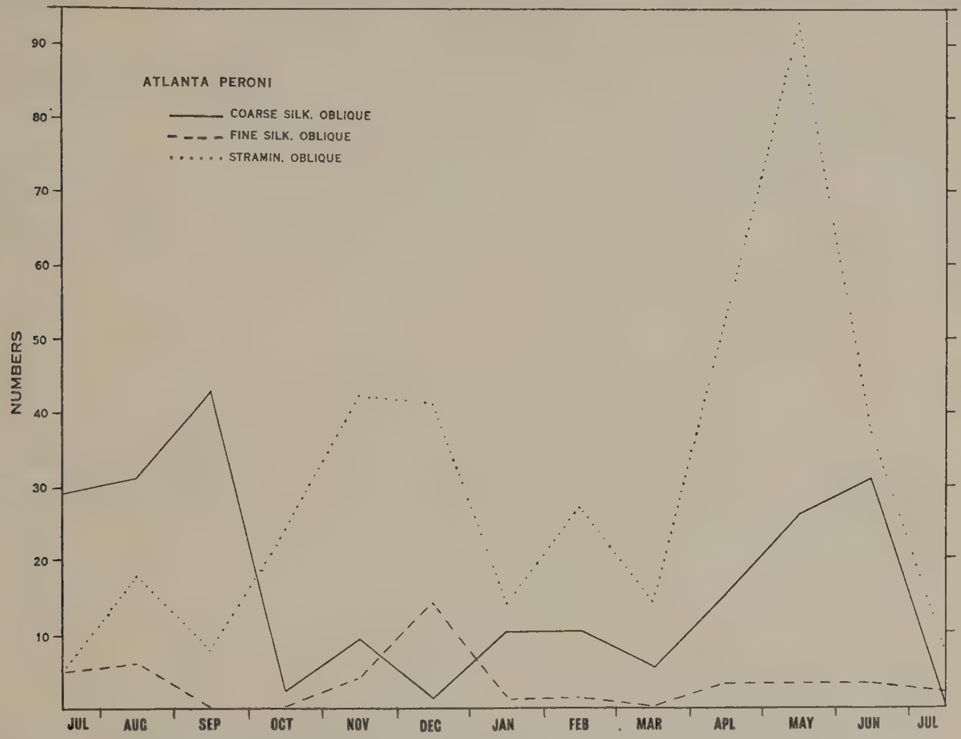
Atlanta peroni, Lesueur, 1817.

The seasonal distribution of *Atlanta peroni* at the weekly station in the barrier reef lagoon is shown in Text-fig. 16, in which the average monthly catches are given for oblique hauls with the stramin, coarse and fine silk nets. There does not appear to have been any very definite seasonal change in abundance. Compared with other plankton animals the numbers of *Atlanta peroni* were very low, and probably too low to allow much significance to be attributed to their variations. The high average catch for May in the stramin net is due to a single catch of 200 at Station 56 (7.v.29). It is noticeable that from July to January the curves for the stramin and coarse silk nets run in opposite directions; this is perhaps due to the prevalence of small individuals in July to September, and larger ones during October to January, but the exact significance is not clear.

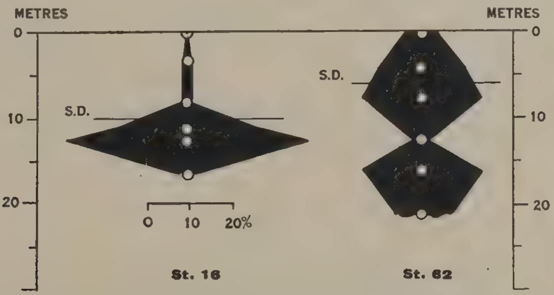
Atlanta peroni was recorded from all stations taken outside the barrier. Miss Massy examined " upwards of six hundred specimens, measuring 1·25 to 4·50 mm. in diameter. Individuals larger than 2·50 mm. were rarely met with. Mr. Eugene O'Mahony kindly allowed me to compare the largest with examples in the Dublin Museum, with which they were in perfect agreement ".

" The largest specimens were taken outside Trinity Opening at about 205 m.," in the bottom stramin net.

Vertical Distribution.—*Atlanta peroni* only occurred at Stations 16 and 62 in sufficient numbers to show its vertical distribution in the barrier reef lagoon in daylight. This species evidently tended to avoid the surface layers, and showed a marked correlation with the transparency of the water in its distribution, occurring considerably nearer the surface at Station 62 when the Secchi disc reading was 6 m. than at Station 16 when it was 10 m. (see Text-fig. 17). It is unlikely that changes in its vertical distribution will have markedly affected the seasonal distribution shown by the oblique hauls.



Text-fig. 16.—Curves showing the average catch of *Atlanta peroni* for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. (Coarse and fine silk and stramin nets, oblique catches.)



Text-fig. 17.—The vertical distribution of *Atlanta peroni* in the daylight in the barrier reef lagoon. Station 16 (3.x.28), 10.13 a.m. to 12.27 p.m.; Station 62 (15.vi.29), 11.20 a.m. to 1.45 p.m. The circles and white dots indicate the average depth at which the hauls were made. Coarse silk townet. S.D., Secchi disc reading. The diagrams are expressed as percentages.

Family Pterotracheidae.

Genus *Pterotrachea*, Forsk., 1775.

Pterotrachea (*Euryops*) *mutabilis*, Tesch, 1906.

The only specimen of *Pterotrachea mutabilis* taken was a female, caught in the stramin net at Station 24 (6.xi.28) in the barrier reef lagoon.

"This measures 45 mm. in length, and has about nine gills. There are no tubercles in front of the eyes, which much resemble those figured by Hesse (1900). Their characteristic shape caused Tesch to found the sub-genus *Euryops*. The body is almost entirely smooth; there are, however, a few tubercles here and there, particularly on the caudal portion; but the caudal fin is without any."

Genus *Firoloida*, Les., 1817.

Firoloida kowalewskii, Vayssière, 1904.

A few specimens of *F. kowalewskii* were caught, both inside the barrier and outside Trinity Opening. They were all taken during September to November, except for a doubtful male in February.

Station 13 (20.ix.28). Coarse silk; "one female with eggs".
Station 15 (2.x.28). Fine silk; "one male".
,, ,, Coarse silk; "one male and two females".
Station 16 (3.x.28). Coarse silk; "three females, one with eggs".
Station 19 (20.x.28). 1 m. coarse silk; "one female".
Station 24 (6.xi.28). Stramin; "one female with eggs".
Station 28 (23.xi.28). Stramin; "one male and one female with eggs".
Station 42 (18.ii.29). Coarse silk; "? one male".

"The last-named (from Station 42) measures only 13 mm., and is not in good condition. The females with ova measured 21–35 mm. in length. Females without ova measured 9–17 mm. The smallest male was 12 mm. in length and the largest 25 mm. At Station 28 the proboscis and one eye of a specimen which must have measured about 30 mm. also occurred. It probably belonged to the present species."

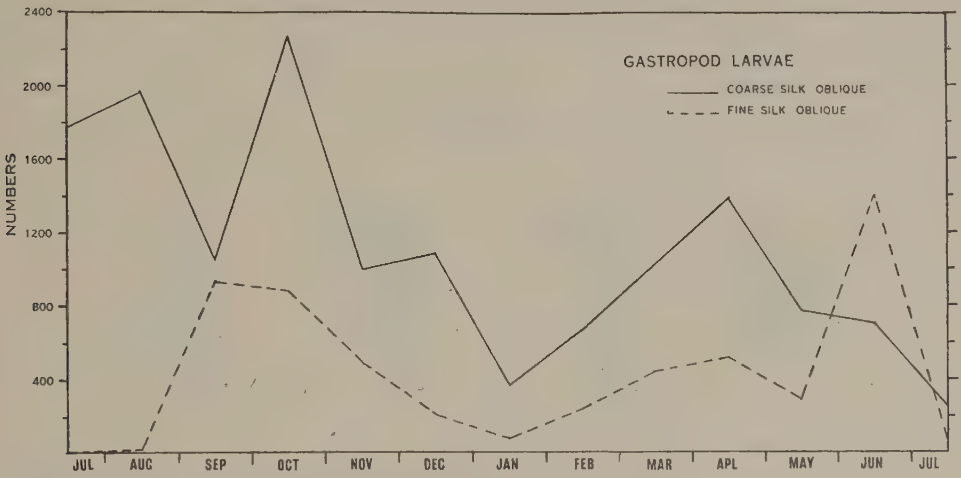
GASTROPODS.

Larval Gastropods.

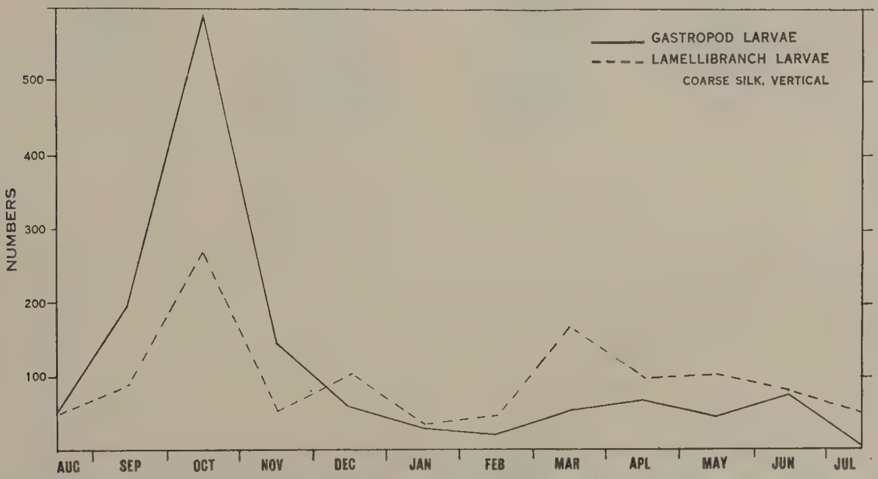
Considerable numbers of larval gastropods (other than Pteropods) occurred in the catches of the coarse and fine silk nets at the weekly station in the barrier reef lagoon. The identification of these small mollusca has not been possible, and many species are probably represented.

The material has, however, been looked through by Prof. Paul Pelseneer, and he records the occurrence of a larva of *Dolium* ("*Macgillivraya pelagica*," MacDonald) at Station 44 (27.ii.29) off Lizard Island, and larvae of *Triforis* at Station 16 (3.x.28) and Station 63 (24.vi.29). In addition a few *Echinospira* larvae were seen.

Very few gastropod larvae were taken in the stramin net, the majority being too small to be retained by the meshes of that material. In Text-figs. 18 and 19 are given the curves for the average catches per month in the coarse and fine silk oblique hauls and the coarse silk vertical hauls, at the stations three miles east of Low Isles in the barrier reef lagoon. There is a definite indication that larval gastropods were slightly more abundant in October than at any other time of the year. They were least abundant in January. It was, however, to be expected that in a region with so rich a molluscan fauna there would be a supply of larval stages of different species in the plankton throughout the year.



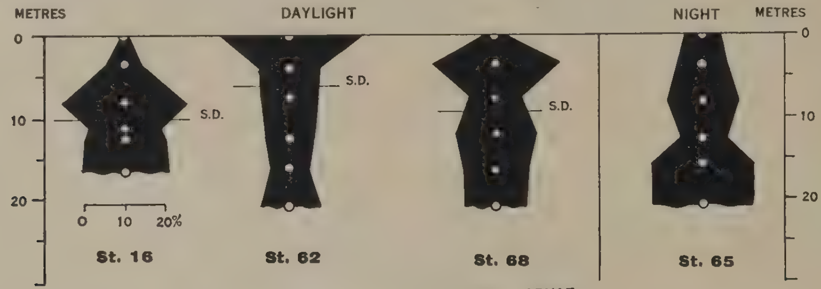
TEXT-FIG. 18.—Curves showing the average catch of Gastropod larvae for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. (Coarse and fine silk nets, oblique hauls.)



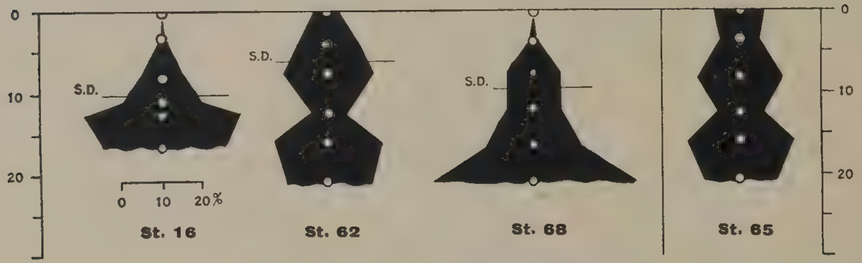
TEXT-FIG. 19.—Curves showing the average catch of Gastropod and of Lamellibranch larvae for each month in the coarse silk net vertical hauls at the position 3 miles east of Low Isles in the barrier reef lagoon.

The numbers of these larval stages in our barrier reef collections were greater than one usually sees in comparable collections from northern waters, and owing to their habit of sinking quickly to the bottom of the vessels in which the plankton was preserved, they were quite a noticeable feature of the silk net collections. We have seen above (p. 236) that on an average throughout the year they formed 35% of the molluscs present in the coarse silk oblique catches, while they only formed 8·7% of the molluscs taken in the stramin net.

The actual numbers in each catch of our collections are given in the tables at the end of Vol. II, No. 6, and owing to the fact that they have not been systematically identified, it is doubtful whether it is worth while to analyse the results further.



GASTROPOD LARVAE



LAMELLIBRANCH LARVAE

Text-fig. 20.—The vertical distribution of Gastropod larvae (above) and Lamellibranch larvae (below) in the daylight and in the dark in the barrier reef lagoon. Station 16 (3.x.28), 10.13 a.m. to 12.27 p.m.; Station 62 (15.vi.29), 11.20 a.m. to 1.45 p.m.; Station 68 (18.vii.29), 10.30 a.m. to 12.55 p.m.; Station 65 (10.vii.29), 9.00 p.m. to 11.25 p.m. The circles and white dots indicate the average depths at which the hauls were made. Coarse silk townet. S.D., Secchi disc reading. The diagrams are expressed as percentages.

Vertical Distribution.—The vertical distribution of gastropod larvae at the four stations made in the barrier reef lagoon is given in Text-fig. 20. These larvae evidently lived sufficiently high in the water in the daytime for reliable results to be obtained by the oblique hauls. There was a tendency for them to live deepest when the water was most transparent.

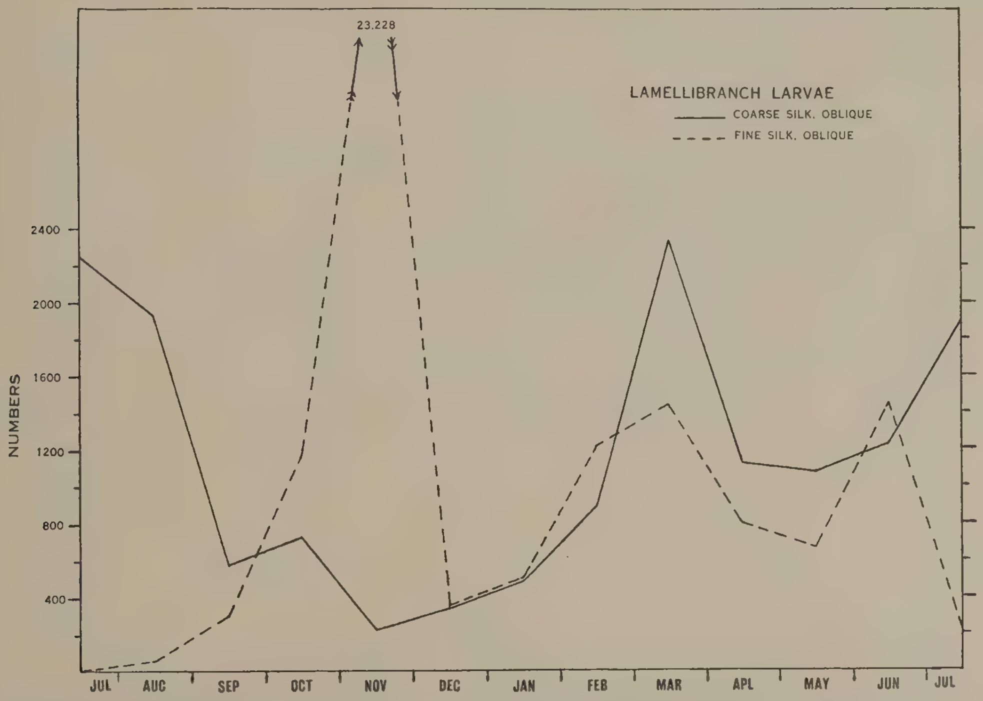
CEPHALOPODA.

The young of Cephalopoda were very scarce in the collections, and when they occurred they were found singly or in small numbers (see Tables at end of Vol. II, No. 6). They appear to have been slightly more abundant at the last few stations in the coarse silk net oblique hauls.

LAMELLIBRANCHIA.

Lamellibranch Larvae.

The larvae of the lamellibranchs have also not been identified. They occurred in most of the catches, being on the whole about as abundant as the gastropod larvae, and forming 39% of the mollusca taken in the oblique hauls with the coarse silk net. They were, however, not taken in the catches of the stramin net, probably because as a whole they settle on the bottom at a smaller size than do some of the gastropods, and there are no large larval stages, such as the Echinospira among the gastropods.



Text-fig. 21.—Curves showing the average catch of Lamellibranch larvae for each month at the position 3 miles east of Low Isles in the barrier reef lagoon. (Coarse and fine silk nets, oblique hauls.)

In Text-figs. 19 and 21 are given the curves for the average catches per month in the coarse and fine silk oblique hauls and in the coarse silk vertical hauls in the barrier reef lagoon. Examination of these figures shows that on the whole lamellibranch larvae may possibly have been slightly more abundant from March to July than at other times of the year. The somewhat irregular nature of the curve, however, prevents us from giving much significance to this, and the most that we can say is that there was no period at which these larval stages were either conspicuously abundant or markedly absent. It is likely that there will be some species breeding at all times during the year, and this is borne out by the fact that when the coarse silk net catches showed a poor occurrence in November, the fine net, which was fishing at the same time, appears to have passed through an enormous swarm of larvae. It is probable that in these warm waters the larval stages are in the plankton for only a very short period before they settle on the bottom.

The actual numbers in each catch of our collections are given in the tables at the end of Vol. II, No. 6.

Vertical Distribution.—The vertical distribution of lamellibranch larvae at the four stations taken in the barrier reef lagoon is shown in Text-fig. 20. These larvae occurred in maximum abundance considerably deeper in the water than did the Gastropod larvae, and it is probable that differences in the transparency of the water may have helped to cause the irregular results shown by the oblique hauls. As the species concerned are not known, however, it is unnecessary to analyse the results further. In the dark, Station 65, they moved much nearer the surface.

The actual numbers occurring in the catches are given in Table VIII in Vol. II, No. 6.

REFERENCES.

Hesse, Richard. 1900. Untersuchungen über die Organe der Lichtempfindung bei niederen Thieren. VI. Die Augen einiger Mollusken. Z. wiss. Zool. LXVIII, pp. 379–477, pls. xxv–xxxii, text-fig. 1.

Meisenheimer, Johannes. 1905. Pteropoda. Wiss. Ergebn. "Valdivia" 1898–1899, IX, Lief. 1, pp. 1–314, pls. i–xxvii, charts i–ix, 35 text-figs.

Pruvot-Fol, Alice. 1924. Étude de quelques Gymnosomes Méditerranéens des pêches de l'"Orvet" en 1921 et 1922. Arch. Zool. Exp. Gén. LXII, pp. 345–400, pls. xv–xvi, text-figs. 1–32.

Tesch, J. J. 1904. The Thecosomata and Gymnosomata of the Siboga Expedition. Siboga Exped. Monog. LII, pp. 1–92, pls. i–vi.

—— 1910. Pteropoda and Heteropoda. Percy Sladen Trust Expedition to the Indian Ocean in 1915. Trans. Linn. Soc. Lond., 2nd ser., XIV, Zoology, pp. 165–189, pls. xii–xiv.

Vayssière, A. 1904. Mollusques Hétéropodes provenant des campagnes des yachts *Hirondelle* et *Princesse-Alice*. Rés. Camp. Sci. Monaco, XXVI, pp. 1–65, pls. i–vi.

TABLE IV.—*Catches of Pteropods and Heteropods in the Oblique Hauls with the Coarse Silk and 1-metre Stramin Nets at the Stations in the Barrier Reef Lagoon 3 miles East of Low Isles.*

		COARSE SILK OBLIQUE.								1 METRE STRAMIN OBLIQUE.							
Station number.	Date.	*Cavolinia longirostris.*	*Cavolinia tridentata.*	*Cavolinia uncinata.*	*Creseis virgula.*	*Creseis acicula.*	*Paraclione pelseneeri.*	*Atlanta peroni.*	*Firoloida kowalewskii.*	*Cavolinia longirostris.*	*Hyalocylix striata.*	*Creseis virgula.*	*Creseis acicula.*	*Paraclione pelseneeri.*	*Atlanta peroni.*	*Pterotrachea mutabilis.*	*Firoloida kowalewskii.*
1	27.vii.28	..	..	..	..	82	..	1	..	..	..	..	30	..	..	..	..
2	30.vii.28	..	..	..	..	44	..	57	..	..	..	..	66	..	10	..	..
3	4.viii.28	..	..	..	..	44	..	25	..	1	..	..	29	..	4	..	..
5	11.viii.28	1	..	..	..	40	..	2	..	1	..	..	84	..	6	..	..
6	17.viii.28	..	..	..	..	52	1	28	..	1	..	..	44	1	33	..	..
7	22.viii.28	..	..	..	..	25	..	101	..	..	..	..	11	..	45	..	..
9	31.viii.28	..	..	..	..	2	..	1	..	1	..	..	34	..	4	..	..
10	4.ix.28	..	..	..	1	85	..	124	..	..	..	..	47	..	14	..	..
12	11.ix.28	..	..	..	1	2	..	1	..	..	..	2	19	..	11	..	..
13	20.ix.28	..	..	..	..	23	..	35	1	2	..	..	34	..	6	..	..
14	26.ix.28	..	..	..	..	3	..	10	..	..	..	..	9	..	2	..	..
15	2.x.28	..	1	1	11	47	..	1	3	1	..	..	47	..	4	..	..
18	15.x.28	..	..	..	..	1253	..	..	..	1	..	10	133	..	25	..	..
22	23.x.28	..	..	..	54	1034	..	5	..	1	..	131	..	..	43	..	..
23	2.xi.28	..	..	..	..	938	..	14	..	..	..	14	11	..	15	..	..
24	6.xi.28	8	..	..	..	330	..	2	..	16	..	..	67	..	73	1	2
25	16.xi.28	..	..	..	220	1860	..	..	..	..	..	..	100	..	14	..	..
27	21.xi.28	18	..	..	2331	156	..	7	..	47	..	..	41	..	90	..	..
30 **30A**	28.xi.28 29.xi.28	..	..	..	..	806	..	24	..	2	4	..	15	..	18	..	..
32	5.xii.28	4	..	..	2013	1008	..	..	..	93	3	..	17	..	2	..	..
33	14.xii.28	19	..	..	4209	6	..	3	..	8	..	29	400	..	59	..	..
34	19.xii.28	16	..	..	..	223	..	..	..	103	..	..	3	..	..	..	..
35	27.xii.28	19	..	..	225	225	..	2	..	99	9	..	27	..	102	..	..
36	4.i.29	23	..	..	1445	..	..	2	..	150	..	3	27	..	10	..	..
37	14.i.29	30	..	..	6	865	..	24	..	330	..	110	761	..	30	..	..
38	21.i.29	170	..	..	2423	477	..	14	..	1216	..	..	20	..	10	..	..
39	30.i.29	102	..	..	..	630	..	1	..	131	..	..	8	..	4	..	..
40	6.ii.29	38	..	..	..	733	..	3	..	54	..	..	40	..	20	..	..
41	13.ii.29	190	..	..	..	804	..	17	..	190	..	..	70	..	47	..	..
42	18.ii.29	10	..	..	..	205	..	11	1	69	..	..	10	..	14	..	..
47	4.iii.29	13	..	..	..	612	..	13	..	34	..	..	51	..	36	..	..
48	15.iii.29	1	..	..	420	420	..	..	..	4	..	..	13	..	..	..	..
51	25.iii.29	1	..	..	1908	292	..	2	..	1	..	..	410	..	7	..	..
52	6.iv.29	50	..	..	83	417	..	30	..	100	..	4	16	..	60	..	..
53	13.iv.29	130	..	..	..	1020	..	..	..	435	..	..	90	..	32	..	..
54	20.iv.29	20	..	..	..	1290	..	2	..	90	..	..	120	..	40	..	..
55	26.iv.29	20	..	..	932	468	..	30	..	50	..	..	10	..	80	..	..
56	7.v.29	50	..	..	..	650	..	14	..	100	..	..	30	..	200	..	..
57	18.v.29	30	..	..	..	40	..	20	..	40	..	6	56	..	50	..	..
58	25.v.29	21	..	..	+	470	..	30	..	90	..	..	180	..	80	..	..
59	31.v.29	80	..	..	..	1060	..	40	..	50	..	..	100	..	40	..	..
60	7.vi.29	11	..	..	+	470	..	60	..	40	..	4	36	..	50	..	..
61	14.vi.29	2	..	..	..	100	..	30	..	40	..	..	40	..	60	..	..
63	24.vi.29	4	..	..	..	730	..	4	..	4	..	..	4	..	..	..	..
64	5.vii.29	..	..	..	..	..	..	+	..	3	..	..	3	..	20	..	..
66	11.vii.29	3	..	..	..	..	1	..	..	3	..	..	8	..	1	..	..
67	17.vii.29	2	..	..	..	28	..	..	..	2	..	..	8	..	..	..	..

TABLE V.—*Catches of Pteropods and Heteropods at Stations other than that 3 miles East of Low Isles.*

Station number.	Date.	Position.	*Cavolinia longirostris.*	*Cavolinia inflexa.*	*Cavolinia quadridentata.*	*Cleodora pyramidata.*	*Hyalocylix striata.*	*Styliola subula.*	*Creseis virgula.*	*Creseis acicula.*	*Gleba* sp.	*Atlanta peroni.*	*Firoloida kowalewskii.*
						COARSE SILK NET.							
8	24.viii.28	I.T.O.	..	..	..	..	..	..	..	9	..	8	..
11	6.ix.28	I.T.O.	..	..	..	..	..	..	1	6	..	6	..
19	20.x.28	O.T.O.	4	5	..	..	..	4	3	..	..	2	1
20	20.x.28	O.T.O.	1	..	..	..	6	..	..	..	..	1	1
21	22.x.28	3 m. E. night	2	..	..	..	..	..	662		..	29	..
26	19.xi.28	I.T.O.	1	..	..	..	..	..	334		..	27	..
28	23.xi.28	O.T.O.	..	3	..	1	..	..	2	14	..	..	..
43	26.ii.29	C.B.	5	..	..	..	..	..	..	2042	..	..	..
44	27.ii.29	Li.I.	20	..	..	..	..	..	..	450	..	1	..
45	28.ii.29	O.C.P.	1	..	..	..	..	..	..	400	..	..	..
46	28.ii.29	I.C.P.	13	..	..	..	..	..	..	1520	..	13	..
49	17.iii.29	I.P.P.	21	..	..	..	..	..	1210		..	50	..
50	18.iii.29	O.P.P.	1	..	..	..	..	..	..	202	..	..	..
						1 METRE STRAMIN NET.							
8	24.viii.28	I.T.O.	..	..	..	..	..	..	..	12	..	10	..
11	6.ix.28	I.T.O.	..	..	..	..	..	..	..	19	..	4	..
19	20.x.28	O.T.O.	1	1	2	..	1	1	..	..	1	..	1
21	22.x.28	3 m. E. night	3	..	..	..	..	..	..	78	..	36	..
26	19.xi.28	I.T.O.	..	..	..	..	..	..	33		..	3	..
28	23.xi.28	O.T.O.	..	1	..	5	5	30	2	2	..	2	3
29	24.xi.28	O.T.O., B.S.N.	7	..	2	3	..	4	1	4	..	2	..
31	2.xii.28	3 m. E., B.S.N.	15	..	..	..	..	..	..	35	..	1	..
43	26.ii.29	C.B.	48	..	..	..	..	..	..	3	..	12	..
44	27.ii.29	L.I.	77	..	..	..	..	..	..	108	..	4	..
45	28.ii.29	O.C.P.	15	..	..	..	..	..	..	12	..	2	..
46	28.ii.29	I.C.P.	33	..	..	..	..	..	..	202	..	27	..
49	17.iii.29	I.P.P.	43	..	..	..	..	..	65	55	..	40	..
50 (i)	18.iii.29	O.P.P.	6	..	..	..	..	..	20	24	..	23	..
50 (ii)	18.iii.29	O.P.P.	2	..	..	..	..	..	..	7	..	2	..

I.T.O., in Trinity Opening; O.T.O., outside Trinity Opening; C.B., off Cape Bedford; Li.I., off Lizard Island; O.C.P., outside Cook's Passage; I.C.P., inside Cook's Passage; I.P.P., inside Papuan Pass; O.P.P., outside Papuan Pass; B.S.N., bottom stramin net. St. 50 (i) = 400 m. St. 50 (ii) = 170 m. (For positions see Chart II, Vol. II, No. 1.)

TABLE VI.—*The Vertical Distribution of Pteropods and Heteropods in the Barrier Reef Lagoon as Shown by Collections with the Coarse Silk Tow-net.*

	Depth in metres.	*Cavolinia longirostris.*	*Creseis* spp.	*Firoloida kowalewskii.*	*Atlanta peroni.*		Depth in metres.	*Cavolinia longirostris.*	*Creseis* spp.	Gymnosomatous pteropod.	*Atlanta peroni.*
Station **16**	S.	..	..	1	..	Station **65**	S.	..	..	2*	..
(3.x.28)	3·1	..	18	..	1	(10.vii.29)	3·7	1	21	..	1
	8·0	..	17	1	1		8·0	3	9	..	11
	11·1	..	90	1	12		12·5	1	40	..	1
	12·5	..	147	..	20		15·5	1	15	..	..
	16·5	..	39	..	2		20·7	1	1	..	..
Station **62**	S.	..	120	..	33	Station **68**	S.	..	..	..	..
(15.vi.29)	4·0	..	380	..	80	(18.vii.29)	3·5	2	57	..	..
	7·5	2	730	..	110		7·5	..	27	..	..
	12·5	7	560	..	15		12·0	..	1	..	1
	16·0	..	1200	..	110		16·5	2	32	..	..
	21·0	..	600	..	50		20·7	..	31	..	..

* Not identified.

COELENTERATA

The coelenterates were numerically of no great importance in the plankton retained by the silk nets, their proportions throughout the year based on the average catches for each month being 1·7% and 0·6% for the coarse and fine silk nets respectively. They played a more important part in the composition of the larger plankton as shown by the catches of the stramin net with an average over the year of 9·5%. We give below the percentages of the total animals formed by the coelenterates on the average for each month for the different nets :

Number of Coelenterata as Percentage of Total Animals Caught in each Month.

	Oblique hauls.		
	Stramin.	Coarse silk.	Fine silk.
1928 :			
July	10·8	0·3	0·1
August	18·5	0·5	0·1
September	12·6	0·1	0·0
October	9·6	1·8	1·2
November	9·6	2·4	0·6
December	7·2 or 30·3*	2·8	1·4
1929 :			
January	15·1	4·8	1·7
February	25·2	2·9	0·9
March	32·9	2·1	0·8
April	1·2	1·7	1·2
May	3·7	0·3	0·2
June	2·9	0·6	0·3
July	1·5	0·3	0·1
Average for year (based on average catch for each month)	9·5*	1·7	0·6

It is evident that at certain times of the year the coelenterates played an important part in the larger plankton, reaching as much as 32·9% of the average monthly catch in the stramin net in March. In the coarse silk net the greatest percentage was only 4·8% in January.

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* Excluding echinoderm larvae.

We give below the percentage composition of the coelenterates for each month divided into the three groups Medusae (including a few young anemones), Siphonophores and Coral planulae for the stramin and coarse silk nets :

Percentage Composition of Average Monthly Catches of Coelenterates.

	Oblique hauls.					
	Stramin.			Coarse silk.		
	Medusae.	Siphonophores.	Coral planulae.	Medusae.	Siphonophores.	Coral planulae.
1928 :						
July	2·1	97·9	..	7·6	92·4	..
August	4·1	95·9	..	17·2	82·8	..
September	4·5	95·5	..	5·0	95·0	..
October	7·7	92·3	..	17·3	82·7	..
November	11·0	89·0	..	12·2	87·8	..
December	12·7	87·3	..	20·2	62·2	17·6
1929 :						
January	15·5	84·5	..	13·5	86·5	..
February	34·2	65·8	..	2·8	97·2	..
March	30·4	69·6	..	14·4	85·6	..
April	26·6	73·4	..	69·4	30·6	..
May	27·0	73·0	..	49·2	50·8	..
June	31·3	68·7	..	83·3	16·7	..
July	35·6	64·4	..	41·9	58·1	..
Average for year (based on average catch for each month)	15·7	84·3	..	20·2	76·4	3·4

These figures show that on the average for the year the Siphonophores far outreached the Medusae in numbers. This preponderance of Siphonophores was consistent throughout the year, but it is noticeable that the medusae became more important in the second half of the twelve months ; examination of the catches shows, however, that this was not due to an actual increase in the numbers of the medusae, but rather to a decrease in the numbers of Siphonophores. Coral planulae appeared in the catches only during December, 1928.

SIPHONOPHORA.

THE identification of the siphonophora has been done by Mr. A. K. Totton, and the results of his examination of the material have already been published in Volume IV, No. 10 of these Reports.

Some thirty-two species were found in the collections, and in addition a few specimens of *Physalia*, *Velella* and *Porpita* were seen in the neighbourhood of Low Isles. Of the species in the collections 4 were Physophorae and 26 Calycophorae. Two new species were found and described, *Cordagalma cordiformis*, Totton, and *Eudoxia russelli*, Totton. Four unnamed species were recorded.

Of the species taken the following 20 occurred in the barrier reef lagoon: *Agalma okenii*, Eschscholtz, *Stephanomia bijuga* (Delle Chiaje), *Abyla haeckeli*, Lens and Van Riemsdijk, *Abylopsis tetragona* (Otto), *Enneagonum hyalinum*, Quoy and Gaimard, *Abylopsis eschscholtzii* (Huxley), *Bassia bassensis* (Quoy and Gaimard), *Sulculeolaria quadrivalvis* (Blainville), *Sulculeolaria monoica* (Chun), *Galetta chuni* (Lens and Van Riemsdijk), *Galetta turgida* (Gegenbaur), *Diphyes dispar*, Chamisso and Eysenhardt, *Diphyes bojani* (Chun), *Diphyes chamissonis*, Huxley, *Chelophyes appendiculata* (Eschscholtz), *Eudoxia russelli*, Totton, *Chelophyes contorta* (Lens and Van Riemsdijk), *Eudoxoides mitra* (Huxley), *Eudoxoides spiralis* (Bigelow), and *Lensia subtiloides* (Lens and Van Riemsdijk).

All the above species, with the exception of *Sulculeolaria monoica*, were recorded from the collections from at least one or other of the stations taken outside the barrier reef and in Trinity Opening, and an additional 12 species were recorded which did not appear in the collections from the barrier reef lagoon, namely *Agalma elegans* (Sars), *Agalma* sp. indet., *Cordagalma cordiformis*, Totton, *Forskalia* sp., *Rosacea ? plicata*, Quoy and Gaimard, *Amphicaryon acaule*, Chun, *Hippopodius hippopus* (Forskål), *Abyla trigona*, Quoy and Gaimard,* *Dimophyes arctica* (Chun), *Lensia campanella* (Moser), *Lensia fowleri* (Bigelow), and *Lensia* spp. indet.

The two species, *D. chamissonis* and *L. subtiloides*, were the only really abundant siphonophores in the barrier reef lagoon.

The analyses of all the catches of siphonophores are given in Tables VIII–X (pp. 272–275). The numbers given in these tables have been obtained by apportioning the different species among the total numbers of siphonophores according to their proportions in the sorted samples from each station. While, therefore, these figures cannot be regarded as strictly accurate, it is felt that they do give a true picture of the relative abundance of the different species concerned. The agreement shown by the catches from the two different nets, stramin and coarse silk, also lends considerable support to the correctness of the conclusions reached as to seasonal abundance and distribution.

When sorting the siphonophores we have counted all loose nectophores, eudoxids and other component parts separately; the total numbers in the tables therefore do not refer only to complete individuals and are thus too high, since in many cases the siphonophore colonies become broken up.

We should like to thank Mr. Totton for the great care and trouble he has taken in counting the specimens from each sample, and the assistance he has given in re-examining and checking critical catches, and by searching through the complete catches.

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* Found in collections since publication of Totton's report.

PHYSOPHORAE.

Family AGALMIDAE.

Genus *Agalma*.

Agalma okenii, Eschscholtz.

This species was only recorded once from the collections made in the barrier reef lagoon, at Station 32 (5.xii.28) in a coarse silk oblique haul.

In other localities it was recorded on five occasions, namely in and outside Trinity Opening at Stations 8 (24.viii.28), 19 (20.x.28), and 28 (23.xi.28), and inside Papuan Pass at Station 49 (17.iii.29).

Agalma elegans, Sars.

This species was only recorded once from the Great Barrier Reef Expedition collections, and on that occasion from outside Trinity Opening at Station 28 (23.xi.28).

Agalma sp.

Nectophores from an undetermined species of *Agalma* were found at Station 50 (18.iii.29), outside Papuan Pass in a stramin net haul from 400 metres.

Genus *Stephanomia*.

Stephanomia bijuga (Delle Chiaje).

This species occurred very sparingly in the barrier reef lagoon, and was also recorded from in and outside Trinity Opening and inside and outside Papuan Pass. In the barrier reef lagoon it was recorded in the months of October and December, 1928, and January, February, April, June and July, 1929, but it was never abundant.

Genus *Cordagalma*.

Cordagalma cordiformis, Totton.

The nectophores upon which Totton bases his description of this new species were taken at Station 19 (20.x.28) outside Trinity Opening. It was not recorded on any other occasion.

"*Athorybia*" *Larvae*.

Two "Athorybia" larvae of Agalmids were found, both occurring in collections from outside Trinity Opening at Station 19 (20.x.28).

Family FORSKALIDAE.

Genus *Forskalia*.

Forskalia sp.

No species of *Forskalia* were found in the collections except at Station 50 (18.iii.29), outside Papuan Pass. The nectophores taken on this occasion were, however, in too poor a condition to make certain identification possible.

CALYCOPHORAE.

Family Prayidae.

Genus *Rosacea*.

Rosacea ? *plicata*, Quoy and Gaimard.

Only one single nectophore of this species was found in the collections, and this occurred in the oblique haul with the stramin net at Station 26 (19.xi.28) in Trinity Opening.

Genus *Amphicaryon*.

Amphicaryon acaule, Chun.

This species was recorded on one occasion only, namely from Station 50 (18.iii.29), outside Papuan Pass in a haul with the stramin net from 400 metres.

Family Hippopodiidae.

Genus *Hippopodius*.

Hippopodius hippopus (Forskål).

This species was only recorded from Station 50 (18.iii.29) outside Papuan Pass in a haul with the stramin net from 400 metres.

Family Abylidae.

Genus *Abyla*.

Abyla haeckeli, Lens and Van Riemsdijk.

This species was recorded only once from the barrier reef lagoon, namely from the position three miles east of Low Isles at Station 15 (2.x.28) in the coarse silk net oblique haul. From other localities it was only recorded at Station 49 (17.iii.29) and Station 50 (18.iii.29) inside and outside Papuan Pass respectively.

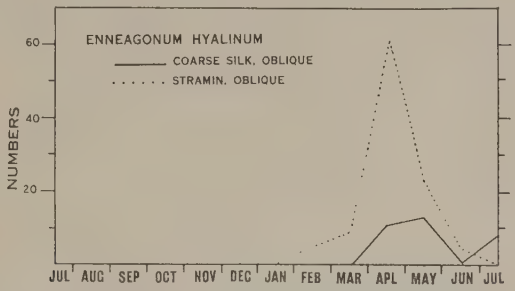
Abyla trigona, Quoy and Gaimard.

This species was found once only in the collections, namely at Station 49 (17.iii.29) in an oblique haul with the coarse silk net inside Papuan Pass. In this haul were found one eudoxid and one gonophore of a eudoxid, which are not recorded in Mr. Totton's report (Vol. IV, No. 10), since he found them whilst searching through the material after publishing.

Genus *Enneagonum*.

Enneagonum hyalinum, Quoy and Gaimard.

This species occurred in the barrier reef lagoon sufficiently frequently to give indications of its seasonal distribution. It was found in the oblique hauls of the coarse silk and stramin nets only during the period January to July, 1929, and was apparently entirely absent before this period. There is evidence that March, April and May were the months in which it was most abundant (see Text-fig. 22). *E. hyalinum* thus occurred in the barrier reef lagoon at the period when the salinity was at its lowest for the year, the averages at 10 metres being for March, April and May, 33·47°/oo, 33·44°/oo and 34·39°/oo respectively. It seems that this species was one of the three which were able to withstand the conditions of the environment during this period of lowered salinity (see p. 270), and it is therefore possibly unusually suited for life in coastal waters.



Text-fig. 22.—The average catches of *Enneagonum hyalinum* for each month in the oblique hauls with the coarse silk and 1-metre stramin nets at the position three miles east of Low Isles, in the barrier reef lagoon.

In the collections from localities other than the position three miles east of Low Isles *E. hyalinum* also occurred in those catches made during the above period of the year. It was found in the collections taken in February and March off Lizard Island in the barrier reef lagoon 100 miles north of Low Isles, and both inside and outside Papuan Pass and outside Cook's Passage. It was, however, never recorded from the region of Trinity Opening, since the collections were made there at the time of year when this species evidently is not prevalent.

Genus *Abylopsis*.

Abylopsis tetragona (Otto).

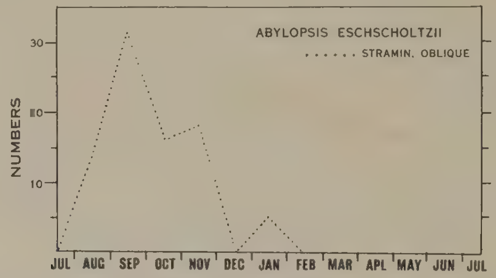
This species occurred very sparingly both in the barrier reef lagoon and outside the barrier. In the barrier reef lagoon it was recorded from collections in the months of August, September, October and November, 1928, and January and June, 1929. It was thus apparently absent during the period of lowered salinity in the lagoon from February to May.

From other localities it was reported from outside Trinity Opening, and also from outside Cook's Passage and Papuan Pass in February and March, during which months it was not recorded from inside the barrier.

Abylopsis eschscholtzii (Huxley).

This species occurred fairly frequently in the barrier reef lagoon, and in sufficient numbers to indicate its seasonal distribution. In Text-fig. 23 is given the curve for the average catches in the stramin net oblique hauls for each month at the position three miles east of Low Isles in the barrier reef lagoon. The period of chief occurrence for *A. eschscholtzii* evidently lay between July, 1928, and February, 1929, its period of greatest abundance being during the months of August, September, October and November. In December and February it was not recorded. An examination of all the collections made with the coarse silk net in the barrier reef lagoon, including the vertical distribution stations, shows that this species was also present in June and July, 1929. It was thus entirely absent in December, and during the period from February to May, when the salinity in the barrier reef lagoon was low.

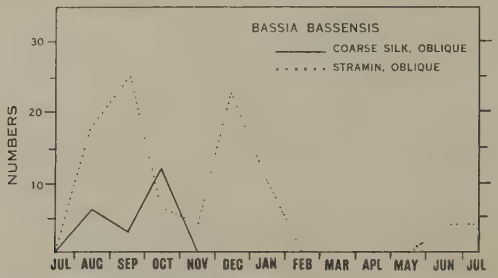
This species was recorded both in and outside Trinity Opening in August, September, October and November. It was also recorded inside Papuan Pass in March, 1929, at Station 49 (17.iii.29), that is, during the period when it was absent from the barrier reef lagoon near Low Isles. It is noteworthy that the salinity inside Papuan Pass on that day was at the surface 34·60°/$_{oo}$, and at 10 m. 34·54°/$_{oo}$; two days before in the Low Isles region it was 33·45°/$_{oo}$ at the surface, and 33·49°/$_{oo}$ at 10 metres.



Text-fig. 23.—The average catches of *Abylopsis eschscholtzii* for each month in the oblique hauls with the 1-metre stramin net at the position three miles east of Low Isles, in the barrier reef lagoon.

Bassia bassensis (Quoy and Gaimard).

This species occurred in the barrier reef lagoon in about the same abundance as did *Abylopsis eschscholtzii*, and it was recorded also during much the same period of time. It was found in both the coarse silk and the stramin net oblique haul catches at the weekly station three miles east of Low Isles during the months August, 1928, to January, 1929, inclusive, and while being absent during February, March, April and May, reappeared in the catches in June and July (see Text-fig. 24). It was thus not recorded in the barrier reef lagoon during the period of low salinity.



Text-fig. 24.—The average catches of *Bassia bassensis* for each month in the oblique hauls with the coarse silk and 1-metre stramin nets at the position three miles east of Low Isles, in the barrier reef lagoon.

From other localities it was recorded in and outside Trinity Opening in August, September, October and November, 1928. It was also found in February outside Cook's

Passage at Station 45 (28.ii.29), and in March inside Papuan Pass at Station 49 (17.iii.29), that is, during the months in which it was not recorded from the barrier reef lagoon near Low Isles. It is again noteworthy, as was mentioned before, under *A. eschscholtzii*, that the salinity at both these stations was considerably higher than the average salinity prevailing in the lagoon channel. It is thus evident that, while a stock is available close at hand in the more saline ocean waters, the species is apparently unable to survive on penetration into the barrier reef lagoon during the period of lowered salinity.

Family DIPHYIDAE.

Sub-family GALETTINAE.

Genus *Sulculeolaria*.

Sulculeolaria quadrivalvis, Blainville.

In the barrier reef lagoon this species was only recorded in occasional catches and then in very low numbers, insufficient to give a reliable picture of its seasonal distribution. It is noticeable, however, that when its occurrences in all the different collections are surveyed together, it was only recorded in the barrier reef lagoon during the months August to December, 1928, inclusive, and in June, 1929. There is thus some evidence that, as with some other species mentioned above, it was absent during the period of low salinity from February to May. The species was found both in and outside Trinity Opening during August and November; but it was also recorded in February and March inside and outside Cook's Passage, and outside Papuan Pass at Stations 45 and 46 (28.ii.29), and Station 50 (18.iii.29). At all of these stations the salinity was considerably higher than that prevailing in most of the barrier reef lagoon during these months.

Sulculeolaria monoica (Chun).

This species was only recorded once from the barrier reef lagoon, in a stramin net oblique haul at Station 15 (2.x.28). It was not recorded from any other locality at which collections were made.

Galetta chuni (Lens and Van Riemsdijk).

This species was only recorded on two occasions at the position three miles east of Low Isles in the barrier reef lagoon, namely at Station 13 (20.ix.28), when it occurred in both the coarse silk and the stramin nets oblique hauls, and at Station 38 (21.i.29) in a coarse silk net oblique haul.

In other localities its presence was more frequent, and it was found from collections in and outside Trinity Opening, and inside and outside Papuan Pass.

Galetta turgida (Gegenbaur).

This species was recorded only once in the barrier reef lagoon, namely in a stramin net catch at Station 13 (20.ix.28). It was also recorded twice outside Trinity Opening, at Stations 19 and 20 (20.x.28), and once outside Papuan Pass, at Station 50 (18.iii.29).

Sub-family Diphyinae.

Genus *Diphyes*.

Diphyes dispar, Chamisso and Eysenhardt.

This species occurred fairly frequently in the barrier reef lagoon, but not in sufficient numbers to give a curve of its seasonal distribution. It was, however, recorded at the position three miles east of Low Isles from both the coarse silk and the stramin net catches in each of the months September, 1928, to January, 1929, inclusive. It was not recorded from either net for any other month. It is thus likely that this species was seasonal in its occurrence in the barrier reef lagoon and not present during the period of low salinity.

It was recorded from in and outside Trinity Opening, and also from the regions of Cook's Passage and Papuan Pass in February and March, in which months it was not recorded from the low salinity water of the barrier reef lagoon.

Diphyes bojani (Eschscholtz).

In the barrier reef lagoon this species was only recorded in the months of September and October at Station 12 (11.ix.28) and Station 13 (20.ix.28) in the stramin net catches, and at Station 16 (3.x.28) at the vertical distribution station with the coarse silk net.

It was recorded much more frequently from other localities, being found in Trinity Opening, and quite abundantly outside Trinity Opening at Station 19 (20.x.28); it was also recorded inside and outside Papuan Pass.

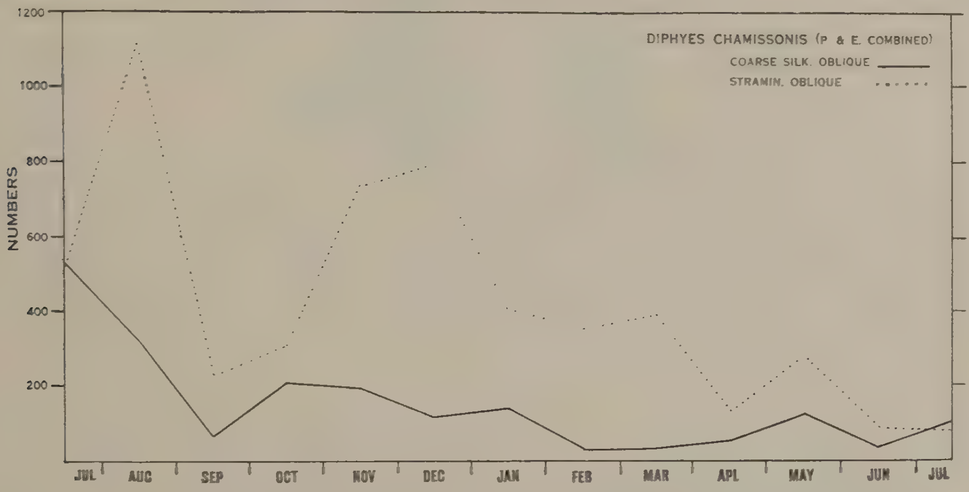
Diphyes chamissonis, Huxley.

This was the most prevalent species in the Great Barrier Reef Expedition collections, and, next to *Lensia subtiloides*, the most abundant. Its presence was recorded at every station at the position three miles east of Low Isles in the barrier reef lagoon with the exception of one, Station 64 (5.viii.29).

In Text-fig. 25 are given the curves for the average catches for each month of *D. chamissonis* (polygastric and eudoxid individuals and component parts combined) in the oblique hauls with the coarse silk and stramin nets at the position three miles east of Low Isles. It shows that on the whole this species was most abundant during the months of July, August, November and December, 1928, and that, while being present throughout the year, there was a tendency for it to decrease in abundance after January, 1929. This decrease is shown more definitely by the curve for the stramin net, and this curve can perhaps be taken as the more reliable of the two, owing to the greater amount of water that the stramin net filters and the consequent high numbers of specimens caught compared with the coarse silk net.

An examination of Tables VIII and IX shows that this species was subject to rather violent fluctuations in numbers from station to station. These fluctuations in the catches have been carefully compared with the variations in the transparency of the water, and, while it was found that some days high numbers caught coincided with the occurrence of very opaque water, on other days the reverse held good. It can be safely concluded after a careful study of this factor that the decrease in abundance of *D. chamissonis* after January, 1929, was actual, and was not a false impression brought about by considerable changes in the vertical distribution of the animal, although, as shown below, this species tended to keep rather deep in the water on days when the water was transparent. No connexion could be found between the week-to-week variations in abundance and the phases of the moon as has been shown for the salps (p. 211).

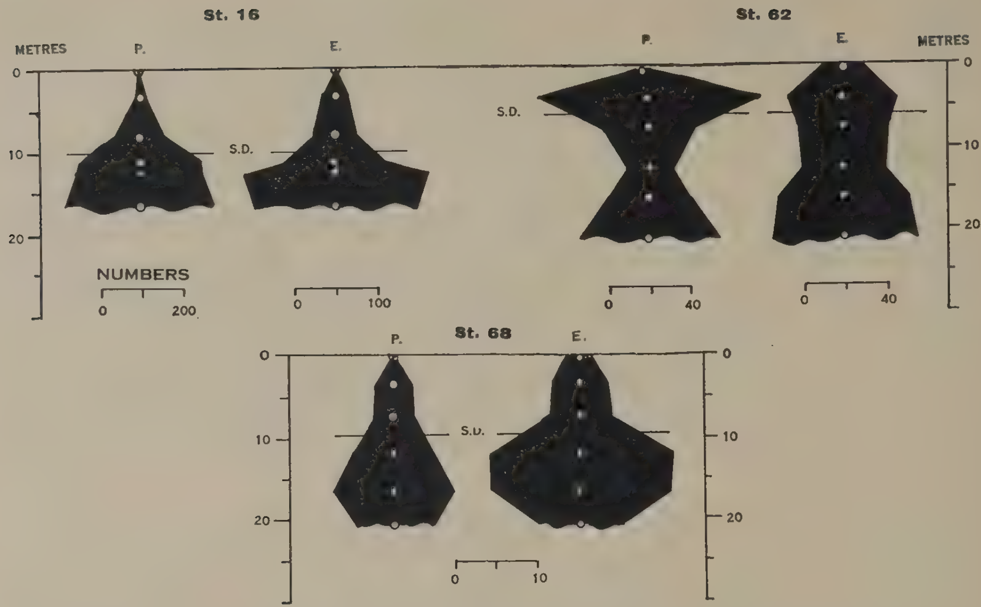
It is noticeable that the gradual decrease in abundance of *D. chamissonis* occurs over the period of lowered salinity in the barrier reef lagoon, and it is possible that the low salinity may be responsible. The species is, however, on the whole apparently well able to withstand this lowering of salinity, and is possibly especially well suited to be a coastal form. Evidence that this species may indeed be a coastal form is afforded on examination of the results of the collections from localities other than in the barrier reef lagoon. We find that while present in Trinity Opening, it was never recorded from any of the stations outside Trinity Opening, and these collections have been very thoroughly searched by Mr. Totton. Furthermore the collections outside Trinity Opening were made during the period of the year when *D. chamissonis* was most abundant in the barrier reef lagoon.



TEXT-FIG. 25.—The average catches of *Diphyes chamissonis* (polygastric and eudoxid individuals combined) for each month in the oblique hauls with the coarse silk and 1-metre stramin nets at the position three miles east of Low Isles, in the barrier reef lagoon.

In the other localities examined, namely Cook's Passage and Papuan Pass, we have further indications supporting the conclusion that this species is a coastal form. While quite abundant inside these passages through the reef, they were present in much diminished numbers outside the passages only a short distance from the barrier reef lagoon.

VERTICAL DISTRIBUTION.—At three of the stations made with the coarse silk net at the position three miles east of Low Isles to study the vertical distribution of the zooplankton, *D. chamissonis* occurred in sufficient numbers to show its vertical distribution in the daylight. We are greatly indebted to Mr. Totton for his kindness and care in sorting and counting the siphonophores from these collections. This species was evidently affected to a certain extent in its behaviour by the transparency of the water, being nearest the surface when the water was least clear (see Text-fig. 26). On clearer days both polygastric and eudoxid stages avoided the surface layers, having their region of maximum abundance



Text-fig. 26.—The vertical distribution of *Diphyes chamissonis* in the daylight at the position three miles east of Low Isles, in the barrier reef lagoon at Station 16 (3.x.28), Station 62 (15.vi.29), and Station 68 (18.vii.29). The white spots indicate the average depths at which the hauls were made. Coarse silk townet. S.D., Secchi disc reading; P., polygastric; E., eudoxid.

below the 10-metre level. It is doubtful, however, whether changes in their vertical distribution will have effected the results shown by the oblique hauls except on the days of greatest transparency.

Genus *Chelophyes*.

Chelophyes appendiculata (Eschscholtz).

This species occurred in fair numbers in the collections from the barrier reef lagoon, but only during the months August to November, 1928, inclusive, and in June, 1929. There is thus evidence that this was another of those species which were absent from the lagoon during the period of lowered salinity.

It was found both in and outside Trinity Opening, but was not recorded from the collections taken in any other locality. It is interesting, therefore, to note that during its period of absence in the barrier reef lagoon it was also absent from the few collections made in February and March in the waters outside the reef in the neighbourhood of Cook's Passage and Papuan Pass.

Chelophyes contorta, Lens and Van Riemsdijk.

This species occurred only sparingly in the collections, and was recorded from the weekly station in the barrier reef lagoon on only three occasions, namely at Station 13 (20.ix.28) and Station 27 (21.xi.28) in the stramin net catches, and at Station 35

(27.xii.28) in the coarse silk oblique haul. Single individuals were also found at two of the vertical distribution stations three miles east of Low Isles, Station 16 (3.x.28) and Station 68 (18.vii.29).

Its presence in the barrier reef lagoon was therefore only recorded for the months of September, October, November and December, 1928, and July, 1929. It would thus appear to have been absent during the period of lowered salinity.

Eudoxia russelli, Totton.

This eudoxid was recorded on one occasion from the barrier reef lagoon, at Station 13 (20.x.28) in a stramin net catch. It was also recorded from one other locality, namely outside Trinity Opening at Station 19 (20.x.28) in a haul with the coarse silk net.

This species is now thought by Mr. Totton to be very probably the eudoxid of *Chelophyes contorta*.

Genus *Eudoxoides*.

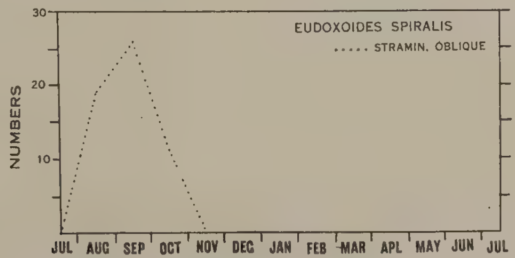
Eudoxoides mitra (Huxley).

This species was recorded only twice from the collections in the barrier reef lagoon, namely in September at Station 12 (11.ix.28) in a stramin net haul, and in October at the vertical distribution Station 16 (3.x.28).

In collections from other localities it was only recorded from outside Trinity Opening and outside Papuan Pass.

Eudoxoides spiralis (Bigelow).

In the collections from the barrier reef lagoon this species was recorded in the months of August, September and October, 1928, and July, 1929. It was quite evidently seasonal in its occurrence, as is shown by the curve for the average catch for each month in the stramin net oblique hauls at the position three miles east of Low Isles (Text-fig. 27). It was also recorded as present at Station 34 (19.xii.28) as a result of a further examination of the residue of the unsampled catch.



Text-fig. 27.—The average catches of *Eudoxoides spiralis* for each month in the oblique hauls with the 1-metre stramin net at the position three miles east of Low Isles, in the barrier reef lagoon.

In localities other than in the barrier reef lagoon it was recorded from in and outside Trinity Opening, and from inside and outside Papuan Pass.

Totton (Vol. IV, No. 10, p. 361) gives figures for the vertical distribution of this species, which show that the few that were caught were distributed well up in the water in the barrier reef lagoon in the daylight.

Genus *Dimophyes.*

Dimophyes arctica, Chun.

This species was recorded from the collections of the Great Barrier Reef Expedition on one occasion only, when one eudoxid was caught in a haul from 580 metres with the coarse silk net at Station 28 (23.xi.28) outside Trinity Opening.

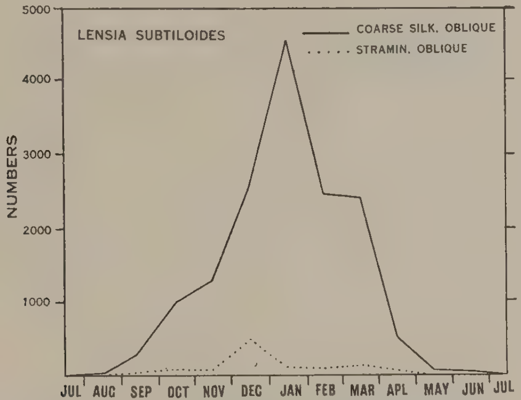
Genus *Lensia.*

Lensia subtiloides (Lens and Van Riemsdijk).

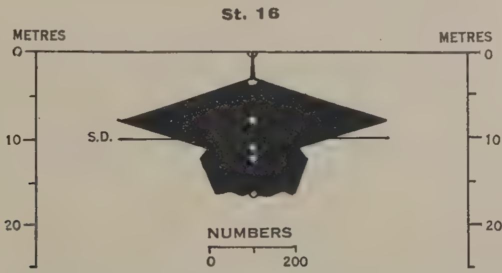
Although not such a constant feature of the zooplankton throughout the year as *Diphyes chamissonis*, *L. subtiloides* was easily the most abundant siphonophore during its period of occurrence. It was recorded in the catches of one or other net every month in the year in the barrier reef lagoon. In Text-fig. 30 (p. 269) are given the curves for the average catches for each month of all siphonophores for all nets. It can be seen that during the period October to March there was a great increase in the numbers of siphonophores indicated. Examination of Tables II and III shows that this increase is produced in the coarse silk net catches by large numbers of very small unidentified siphonophores. The tables show also that the seasonal distribution of these small siphonophores coincides more or less with that shown by the stramin net oblique hauls and those of the coarse silk net for *Lensia subtiloides*. Mr. Totton made a special examination of the collections with the stramin net from Stations 32, 35 and 36, and with the coarse silk net from Stations 27, 33, 34, 36, 38 and 41, at which these small siphonophores were exceptionally numerous. His examinations showed that, while there were a few small polygastric and eudoxid specimens of *D. chamissonis* present, the bulk of these small siphonophores consisted of *L. subtiloides*. The numbers of these small unidentified siphonophores have therefore been used to construct the curve for the monthly abundance of *L. subtiloides* in the coarse silk net oblique catches in Text-fig. 28; the same figure shows also the curve for the identified specimens from the stramin net catches. While the stramin net shows a similar seasonal distribution to that shown by the coarse silk net, the very much greater numbers taken in the coarse silk net are at once evident. The majority of these small individuals were too small to be retained by the stramin material. Examination of Text-fig. 30 shows how this species predominated over all others in abundance in the coarse silk net catches when it was present, the form of the curve from September to May following that for *L. subtiloides* in Text-fig. 28.

It is evident that this species was fully able to withstand the conditions of lowered salinity in the barrier reef lagoon during the period from February to May. It is noticeable, however, that during this period the numbers of individuals were rapidly decreasing, but it is not possible to decide whether this decrease is a result of the lowered salinity, or whether it is not perhaps the normal decrease in the sequence of the seasonal distribution of this species. In this connexion it is interesting to note that the general trend of the curve for seasonal abundance follows very closely that for the temperature of the water, the period of maximum abundance coinciding with the time of highest temperature when temperatures of 28° C. and over were recorded. *L. subtiloides* became relatively very rare when the temperature dropped below 24° C.

This species thus seems specially suited for living in coastal waters of high temperature, and it is perhaps significant that it was never recorded from the collections made in February and March outside Cook's Passage and outside Papuan Pass, while the small unidentified siphonophores were abundant inside Papuan Pass.



Text-fig. 28.—The average catches of *Lensia subtiloides* for each month in the oblique hauls with the coarse silk and 1-metre stramin nets at the position three miles east of Low Isles, in the barrier reef lagoon.



Text-fig. 29.—The vertical distribution of *Lensia subtiloides* in the daylight at the position three miles east of Low Isles, in the barrier reef lagoon, at Station 16 (3.x.28). The white spots indicate the average depths at which the hauls were made. Coarse silk tow-net. S.D., Secchi disc reading.

Vertical Distribution.—Only one of the stations for the study of the vertical distribution of the zooplankton in the barrier reef lagoon was made during the period when *L. subtiloides* was at all common, namely Station 16 (3.x.28), when this species was just beginning to become abundant. The vertical distribution on this occasion is shown in Text-fig. 29, and it can be seen that, while avoiding the surface layers, the species was living well up in the water in the daylight.

Lensia subtilis (Chun).

This species was not recorded from any of the collections in the barrier reef lagoon. In the collections from other localities it was only recorded at Station 49 (17.iii.29) inside Papuan Pass and Station 50 (18.iii.29) outside Papuan Pass.

Lensia campanella (Moser).

This species was not recorded from any of the collections in the barrier reef lagoon. In the collections from other localities it was only recorded from Station 19 (20.x.28) outside Trinity Opening, Station 49 (17.iii.29) inside Papuan Pass, and Station 50 (18.iii.29) outside Papuan Pass.

Lensia fowleri (Bigelow).

There is only one record of this species in the Great Barrier Reef Expedition collections, and that was the presence of a single nectophore at Station 28 (23.xi.28) outside Trinity Opening.

Lensia spp. indet.

A few specimens of unidentified *Lensia* species occurred outside Trinity Opening at Stations 19 and 20 (20.x.28) and Station 28 (23.xi.28), and also at Station 50 (18.iii.29) outside Papuan Pass.

RHIZOPHYSALIAE.

Family Physalidae.

No specimens of *Physalia* were collected during the expedition, but one or two were recorded as having been seen in August, and on 20th and 23rd September, 2nd October and 6th November, 1928. They were never seen abundantly.

CHONDROPHORAE.

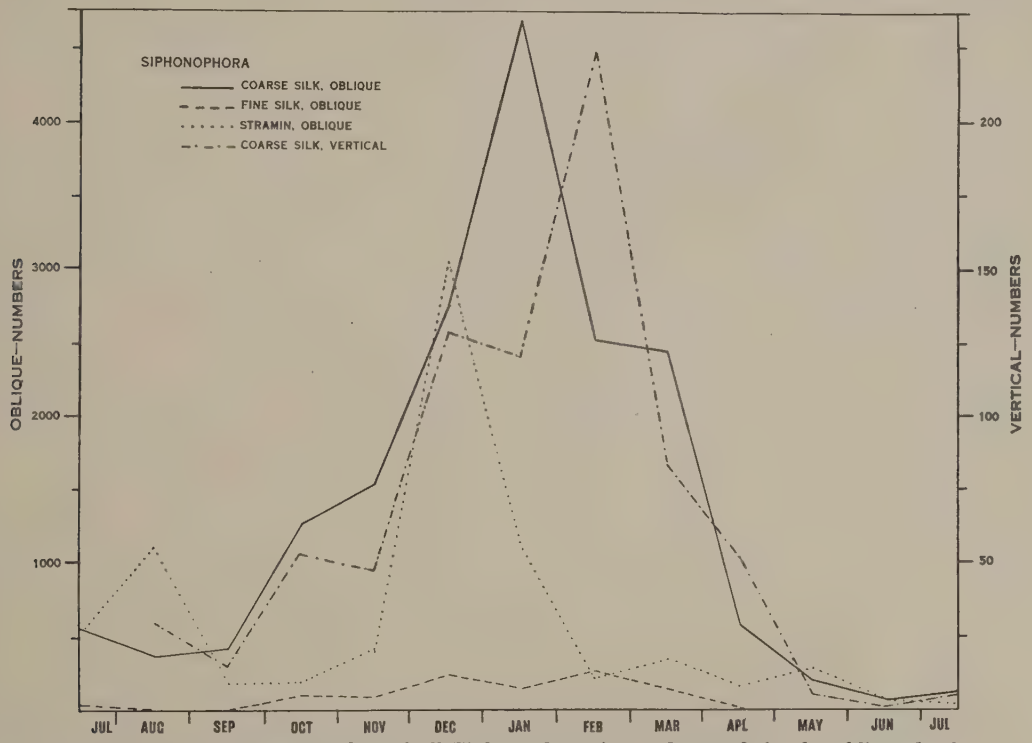
On 12th August, 1928, a *Velella* sp. was seen, and on 15th September a *Porpita* sp., both washed up on the shores of Low Isles. They were never seen at sea in abundance.

On the Occurrence of Siphonophores.

In Text-fig. 30 are given the curves for the average catches of all siphonophores for each month at the weekly station in the barrier reef lagoon for all nets. We have seen above that two species alone predominated in these catches, *Lensia subtiloides* and *Diphyes chamissonis*; the curves in Text-fig. 30 are therefore practically a replica of those for these two species combined, and of these *L. subtiloides* was responsible for the major fluctuations in abundance during the year.

In Table VII we have indicated the months in which each species was recorded in one or other net, either at the weekly station, or the vertical distribution stations in the barrier reef lagoon near Low Isles. In this table a thin cross indicates that the species was recorded for the month in question in a catch or catches of one type of net only, either coarse silk or stramin; a thick cross indicates that the species was recorded from both the coarse silk and the stramin net catches. The stramin net is perhaps more usually responsible for the thin crosses, since it is more likely to have caught the rarer species on account of the greater amount of water it filters compared with the coarse silk net. Thus while the thin crosses can be taken to indicate the range of seasonal occurrence, the thick crosses will generally be found in those months in which the different species were most abundant.

Twenty species were recorded from the barrier reef lagoon, and we have indicated at the foot of Table VII the number of species occurring in each month. It is at once evident that there was a period during the months of February, March, April and May when the number of species was very low compared with the rest of the year, *Enneagonum hyalinum*, *Diphyes chamissonis* and *Lensia subtiloides* being the only species occurring regularly during this period. At other times of the year many more species occurred, the maximum number recorded being 16 in October. It is likely also that a closer examination of the catches might have led to a slight increase in the numbers of species for some of the other months, since the numbers recorded in October were raised by the very careful search made on the catches from the hauls taken at the vertical distribution station. The low numbers in July, 1928, may perhaps also be disregarded, as the results rest only on the collections from the first two stations. It is remarkable that not a single specimen of the remaining 15 species should have been recorded from the large number of collections (28 in all) made during the period from February to May inclusive, and this can surely be taken as evidence that these species must have been almost entirely absent from the barrier reef lagoon in the area studied. The same held good also for the collections made further to the north off Cape Bedford.



TEXT-FIG. 30.—The average catches of all Siphonophora for each month in the oblique hauls with the coarse and fine silk and 1-metre stramin nets, and in the vertical hauls with the coarse silk net, at the position three miles east of Low Isles, in the barrier reef lagoon.

There must be some factor to account for the continued disappearance of so many species from the area, and we must now turn to the hydrographical data. At the foot of

Table VII we have inserted the average salinities and temperatures at a depth of 10 metres in the barrier reef lagoon for each month. It can at once be seen that the period of absence of most of the species of siphonophores from the barrier reef lagoon coincided with that for low salinity, which was a result of the heavy rains prevalent at that time of year. The average salinities for the months of February, March, April and May were lower than those for any other month in the year, being 33·63°/₀₀, 33·47°/₀₀, 33·44°/₀₀ and 34·39°/₀₀ respectively. Now it was during this period of lowered salinity that the collections were made in the region of Cook's Passage and Papuan Pass, and we have seen in the previous pages that many species were recorded from these localities, especially from the outside waters, and of these species some were those which were then absent from the waters of the barrier reef lagoon, near Low Isles. It is a significant fact that the salinity of these outside waters was in the neighbourhood of 34·5°/₀₀ and above, and that it is just about at this salinity that the majority of the species begin to disappear from the catches in January, and reappear in June. Examination of the tables shows that by 14th January the period of scarcity of species had begun. The salinities at 10 metres in the lagoon during January were as follows: 4th January, 34·95°/₀₀; 14th,

TABLE VII.—*Occurrence of Different Species of Siphonophores in the Barrier Reef Lagoon.*

	1928.						1929.						
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.
Agalma okenii . .						+							
Stephanomia bijuga .				+		**+**	+			+		+	+
Abyla haeckeli . .				+									
Abylopsis tetragona .		+	+	+	+		+					+	
Enneagonum hyalinum .							**+**	+	+	**+**	**+**	**+**	+
Abylopsis eschscholtzii .	+	**+**	**+**	+	+		+					+	+
Bassia bassensis . .		**+**	**+**	**+**	+	**+**	+					**+**	**+**
Sulculeolaria quadrivalvis		+	+	+	+	**+**						+	
Sulculeolaria monoica .				+									
Galetta chuni . .			**+**	+		+	+						
Galetta turgida . .						+							
Diphyes dispar . .			**+**	**+**	**+**	**+**	**+**						
Diphyes bojani . .			+	+									
Diphyes chamissonis .	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**
Chelophyes appendiculata		+	**+**	**+**	+							+	
*Chelophyes contorta** .			+	+	+	+							+
Eudoxides mitra . .			+	+									
Eudoxoides spiralis .		+	**+**	+									+
Lensia subtiloides . .	**+**	+	**+**	**+**	**+**	**+**	**+**	**+**	+	**+**	+	+	+
Small, unidentified .		+	+	+	+	**+**	**+**	+	**+**	**+**	**+**	+	+
Number of species† .	3	8	13	16	9	10	9	3	3	4	3	9	8
Salinity‡ (average monthly) °/₀₀	35·16	35·11	35·30	35·34	35·20	35·16	34·43	33·63	33·47	33·44	34·39	34·73	34·99
Temperature‡ (average monthly) °C.	22·2	22·3	24·4	25·8	27·1	28·4	28·7	28·8	28·1	26·8	24·4	22·9	21·5

+ Present in both stramin and coarse silk nets. + Present in one net only.

* *Eudoxia russelli* has been excluded in this list as possibly belonging to this species.

† Excluding "small, unidentified", which are mostly *L. subtiloides*.

‡ At 10 metres at the position three miles east of Low Isles.

34·43°/$_{oo}$; 21st, 34·50°/$_{oo}$, and 30th, 33·82°/$_{oo}$. The salinities at the end of May and beginning of June, when many species reappeared in the lagoon, were on 31st May, 34·53°/$_{oo}$, and on 7th June, 34·93°/$_{oo}$. Meanwhile on 28th February, outside Cook's Passage the salinity was 34·53°/$_{oo}$; outside Papuan Pass on 18th March it was 34·56°/$_{oo}$; and inside Papuan Pass on 17th March, 34·54°/$_{oo}$; at these positions there was no scarcity of species.

It is thus very difficult to avoid the inference that from February to May the water in the barrier reef lagoon, owing to its lowered salinity, becomes uninhabitable to the majority of siphonophore species which are probably present in the more saline waters outside the reef, and can invade the lagoon successfully at other times of the year. Bigelow (1911, p. 381) has said that siphonophores "are almost a negligible factor in waters with a salinity less than 35 per mille", and it seems that this generalization holds good for the waters of the barrier reef lagoon, where the limiting salinity is more accurately about 34·5°/$_{oo}$. It should, however, be pointed out that two of the three outside species that occurred in any numbers, *Eudoxoides spiralis* and *Abylopsis escholtzii*, were already showing indications of a decrease some time before January (see Text-figs. 23 and 27, pp. 260 and 265). The numbers taken were, however, very low, and it is impossible to say whether this early decrease is of real significance.

The occurrence of *Diphyes chamissonis*, *Lensia subtiloides* and *Enneagonum hyalinum* during this period of lowered salinity is of great interest, and points to the possibility that these species are specially adapted to life in shallow coastal waters. If this be true it is the first time that any species of siphonophores have been definitely recognized as coastal species in a group which is so predominantly oceanic. *Enneagonum hyalinum* indeed was peculiar in that it only appeared in the collections in January, when the salinity was decreasing, and was then prevalent right through the period of low salinity.

In considering these results the possible importance of temperature must not be lost sight of, and there is a chance that the majority of the species cease active reproduction when the temperature is reaching its maximum between December and February. It seems unlikely, though, that this should have been the cause of the paucity of species in the barrier reef lagoon after February, since in that month and in March the temperature was just as high in the waters outside the reef where the absent species were still found.

Another possible cause in the decrease in numbers of species might be looked for in the turbidity of the water. One might suppose that during the rainy season much silt might have been brought down into the lagoon from the land and destroyed the siphonophores, which require very pure water. But there was no indication that such was the case; observations showed that perhaps if anything the water was slightly more transparent in February on account of the unusually calm conditions then prevailing, although in March and April it was at times very turbid (Orr, Vol. II, No. 3, p. 46).

Among the siphonophores recorded from the Great Barrier Reef Expedition collections *Amphicaryon acaule*, *Lensia subtilis* and *Chelophyes appendiculata* have so far been recorded only from the Atlantic and Pacific Oceans, and *Diphyes chamissonis* and *Lensia subtiloides* only from the Indo-Pacific region. All the rest with the exception of the two newly described species are known from all three oceans (Bigelow, 1911 and 1931; Lens and Van Riemsdijk, 1908; Moser, 1925). All are warm-water species except *Stephanomia bijuga*, which has a wide distribution, occurring both in warm and cold water (if its synonymy with *S. cara* be correct), and *Dimophyes arctica*, which is a bipolar form that has been recorded widely over all oceans, and probably occurs in the warmer zone, chiefly in

[*Continued on p. 276.*

TABLE VIII.—*Siphonophora Occurring in Oblique Hauls of the 1-metre Stramin Net at the Stations in the Barrier Reef Lagoon 3 miles East of Low Isles.*

Station number.	Date.	*Stephanomia bijuga.*	*Abyla haeckeli.*	*Abylopsis tetragona.*		*Enneagonum hyalinum.*		*Abylopsis eschscholtzii.*		*Bassia bassensis.*		*Sulculeolaria quadrivalvis.*	*Sulculeolaria monoica.*	*Galetta chuni.*	*Galetta turgida.*	*Diphyes dispar.*		*Diphyes bojani.*		*Diphyes chamissonis.*		*Chelophyes appendiculata.*		*Chelophyes contorta.*	*Eudoxia russelli.*	*Eudoxoides mitra.*	*Eudoxoides spiralis.*	*Lensia subtiloides.*	Small, unidentified.
		P.	P.	P.	E.	P.	E.	P.	E.	P.	E.	P.	P.	P.	P.	P.	E.	P.	E.	P.	E.	P.	E.	P.	E.	E.	P.	E.	
1	27.vii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	356	252	..	..	..	..	..	..	2	..
2	30.vii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	347	62	..	..	..	..	..	..	..	..
3	4.viii.28	..	..	..	..	..	..	..	1	..	27	..	..	..	..	..	..	..	..	163	1213	1	..	..	..	..	..	14	..
5	11.viii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	212	424	..	..	..	..	..	..	..	..
6	17.viii.28	..	..	3	..	..	..	2	3	3	3	3	..	..	..	..	..	..	..	165	1585	9	..	..	..	..	93	155	..
7	22.viii.28	..	..	1	2	..	..	2	8	2	7	..	..	..	..	..	..	..	..	8	156	5	..	..	..	..	..	..	..
9	31.viii.28	..	..	..	..	..	..	..	49	12	37	..	..	..	..	..	..	..	..	161	1490	..	..	..	..	..	..	..	..
10	4.ix.28	..	..	2	..	..	..	..	9	..	31	..	..	..	..	..	..	..	..	69	235	11	..	..	..	..	9	..	..
12	11.ix.28	..	..	1	..	..	..	20	60	..	53	2	..	..	..	3	8	..	2	24	76	2	..	..	..	8	28	2	..
13	20.ix.28	..	..	..	..	..	..	1	25	1	11	1	..	+	+	..	1	1	11	56	210	23	11	23	10	..	..	79	..
14	26.ix.28	..	..	..	..	..	..	..	11	2	4	..	..	..	..	..	..	..	..	15	197	20	..	..	..	..	66	..	..
15	2.x.28	..	2	..	..	..	..	2	5	..	2	..	2	..	..	2	..	..	..	53	45	9	..	..	..	..	22	111	..
18	15.x.28	..	..	..	..	..	..	..	24	..	20	..	..	..	..	..	..	..	..	44	200	12	..	..	..	..	12	24	..
22	23.x.28	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..	..	258	310	..	..	..	..	..	..	124	..
23	2.xi.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	13	778	2	..	..	..	..	..	..	..
24	6.xi.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	27	..	..	..	9	424	..	..	..	..	..	..	27	..
25	16.xi.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	874	1173	..	..	..	..	..	..	183	..
27	21.xi.28	..	..	..	..	..	..	4	85	..	21	..	..	..	..	..	..	..	..	26	247	..	..	2	..	..	..	106	..
30	28.xi.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11	92	..	..	..	..	..	..	..	..
32	5.xii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	184	491	..	..	..	..	..	..	1105	2600
33	14.xii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	17	..	..	488	280	..	..	..	..	..	..	505	1600
34	19.xii.28	2	..	..	..	..	..	..	..	..	91	..	..	..	..	..	137	..	..	1100	366	..	..	..	..	..	+	366	..
35	27.xii.28	1	..	..	..	..	..	..	..	..	..	13	..	..	..	14	..	..	..	272	..	..	..	..	..	..	..	+	2600
36	4.i.29	2	..	..	1	..	..	20	..	..	40	..	..	..	..	2	..	..	..	125	160	..	..	..	..	..	..	20	2740
37	14.i.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	424	30	..	..	..	..	..	..	46	..
38	21.i.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	511	77	..	..	..	..	..	..	102	..
39	30.i.29	2	..	..	..	..	4	..	..	..	..	..	..	..	..	..	..	..	..	105	187	..	..	..	..	..	..	247	..
40	6.ii.29	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	99	187	..	..	..	..	..	..	43	..
41	13.ii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	49	478	..	..	..	..	..	..	33	..
42	18.ii.29	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..	..	..	..	178	59	..	..	..	..	..	..	178	..
47	4.iii.29	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	86	80	..	..	..	..	..	..	80	460
48	15.iii.29	..	..	..	..	..	25	..	..	..	..	..	..	..	..	..	..	..	..	197	469	..	..	..	..	..	..	49	..
51	25.iii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	191	143	..	..	..	..	..	..	176	..
52	6.iv.29	3	..	..	..	18	123	..	..	..	..	..	..	..	..	..	..	..	..	108	180	..	..	..	..	..	..	108	..
53	13.iv.29	..	..	..	..	4	81	..	..	..	..	..	..	..	..	..	..	..	..	..	50	..	..	..	..	..	..	100	..
54	20.iv.29	..	..	..	..	1	6	..	..	..	..	..	..	..	..	..	..	..	..	17	86	..	..	..	..	..	..	..	..
55	26.iv.29	..	..	..	..	..	9	..	..	..	..	..	..	..	..	..	..	..	..	51	30	..	..	..	..	..	..	30	200
56	7.v.29	..	..	..	..	6	42	..	..	..	..	..	..	..	..	..	..	..	..	6	6	..	..	..	..	..	..	..	400
57	18.v.29	..	..	..	..	..	32	..	..	..	..	..	..	..	..	..	..	..	..	126	26	..	..	..	..	..	..	26	600
58	25.v.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	37	543	..	..	..	..	..	..	..	..
59	31.v.29	..	..	..	..	4	11	..	..	..	..	..	..	..	..	..	..	..	..	74	301	..	..	..	..	..	..	..	..
60	7.vi.29	..	..	2	..	..	..	..	..	..	12	1	..	..	..	..	..	..	..	2	2	11	..	..	..	..	..	..	..
61	14.vi.29	..	..	..	..	..	16	..	..	..	..	..	..	..	..	..	..	..	..	59	45	..	..	..	..	..	..	..	..
63	24.vi.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	63	85	..	..	..	..	..	..	12	..
64	5.vii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10
66	11.vii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	10	..	..	..	..	..	..	..	..
67	17.vii.29	..	..	..	..	..	..	..	..	14	..	..	..	..	..	..	..	..	..	103	103	..	..	..	..	..	..	..	..

P. = polygastric stage. E. = Eudoxid.

+ Implies that specimens were found only during examination of the remainder of the total catch from which the samples for counting had been taken.

TABLE IX.—*Siphonophora Occurring in Oblique Hauls of the Coarse Silk Tow-net at the Stations in the Barrier Reef Lagoon 3 miles East of Low Isles.*

Station number.	Date.	*Agalma okenii.*	*Stephanomia bijuga.*	*Abylopsis tetragona.*		*Enneagonum hyalinum.*		*Abylopsis eschscholtzii.*		*Bassia bassensis.*		*Sulculeolaria quadrivalvis.*	*Galetta chuni.*	*Diphyes dispar.*		*Diphyes bojani.*	*Diphyes chamissonis.*		*Chelophyes appendiculata.*	*Chelophyes contorta.*	*Eudoxoides spiralis.*	*Lensia subtiloides.*	Small, unidentified.
		P.	P.	P.	E.	P.	E.	P.	E.	P.	E.	P.	P.	P.	E.	E.	P.	E.	P.	P.	P.	P.	
1	27.vii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	553	340	..	..	..	..	..
2	30.vii.28	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	25	144	..	..	..	15	..
3	4.viii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	43	332	1	..	..	..	..
5	11.viii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	231	39	..	..	..	..	..
6	17.viii.28	..	..	..	..	..	..	..	..	..	15	..	..	..	..	..	188	253	..	..	..	..	..
7	22.viii.28	..	..	..	..	..	..	..	13	13	..	..	..	..	..	..	13	172	..	..	..	..	200
9	31.viii.28	..	..	..	..	..	..	..	14	..	..	..	..	..	..	..	76	254	..	..	..	..	..
10	4.ix.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	7	82	1	..	..	..	600
12	11.ix.28	..	..	..	..	..	..	..	..	..	..	..	..	..	14	..	..	42	..	..	14	..	..
13	20.ix.28	..	..	..	..	..	..	1	..	..	2	12	+	..	..	..	11	53	1	..	..	1	600
14	26.ix.28	..	..	..	..	..	..	..	..	4	7	..	..	4	..	4	11	38	116	..	38	..	..
15	2.x.28	..	..	4	4	..	..	..	..	7	9	4	..	..	..	..	4	7	33	..	..	..	600
18	15.x.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	432	137	..	..	..	11	2000
22	23.x.28	..	..	..	..	..	..	..	..	..	17	..	..	..	17	..	3	34	..	..	..	51	400
23	2.xi.28	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	4	176	..	..	..	13	200
24	6.xi.28	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	10	119	..	..	..	..	1400
25	16.xi.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	194	377	..	..	..	229	1600
27	21.xi.28	..	..	..	1	..	..	..	..	..	..	..	..	..	20	..	2	42	..	..	..	+	3200
30a	29.xi.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	12	23	..	..	..	..	..
32	5.xii.28	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	33	144	..	..	..	78	1400
33	14.xii.28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	36	20	..	..	..	41	3600
34	19.xii.28	..	2	..	..	..	..	..	..	..	46	..	..	..	5	..	18	113	..	..	..	+	3200
35	27.xii.28	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	61	40	..	10	..	30	2000
36	4.i.29	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	87	28	..	..	..	14	3400
37	14.i.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	70	20	..	..	..	10	1400
38	21.i.29	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	170	12	..	..	..	+	12,400
39	30.i.29	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	168	..	..	..	..	12	1000
40	6.ii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2410
41	13.ii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	40	..	..	..	+	3600
42	18.ii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	30	10	..	..	..	10	1400
47	4.iii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1420
48	15.iii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	35	..	..	..	..	1400
51	25.iii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	13	23	..	..	..	..	4400
52	6.iv.29	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	45	35	..	..	..	10	400
53	13.iv.29	..	..	..	..	8	12	..	..	..	..	..	..	..	..	..	12	38	..	..	..	..	800
54	20.iv.29	..	..	..	..	1	2	..	..	..	..	..	..	..	..	..	3	62	..	..	..	..	200
55	26.iv.29	..	..	..	..	3	8	..	..	..	..	..	..	..	..	..	8	3	..	..	..	28	600
56	7.v.29	..	..	..	..	..	37	..	..	..	..	..	..	..	..	..	15	7	..	..	..	..	..
57	18.v.29	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	8	68	..	..	..	..	..
58	25.v.29	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	19	270	..	..	..	..	200
59	31.v.29	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	20	70	..	..	..	..	..
60	7.vi.29	..	..	..	..	1	..	..	10	..	1	..	..	..	..	..	14	23	..	..	..	..	..
61	14.vi.29	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	12	45	..	..	..	..	..
63	24.vi.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	90
66	11.vii.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	50	..	..	..	..	..	..
67	17.vii.29	..	..	..	..	..	17	..	..	..	17	..	..	..	..	..	83	83	..	..	..	..	..

P. = Polygastric stage. E. = Eudoxid.

+ Implies that specimens were found only during examination of the remainder of the total catch from which the samples for counting had been taken.

TABLE X.—*Siphonophora from Stations other*

Station number.	Date.	Position.	*Agalma okenii.*	*Agalma elegans.*	*Agalma* sp.	"*Athorybia*" larvae.	*Stephanomia bijuga.*	*Cordagalma cordiformis.*	*Forskalia* sp.	*Rosacea ? plicata.*	*Amphicaryon acaule.*	*Hippopodius hippopus.*	*Abyla haeckeli.*	*Abyla trigona*	*Abylopsis tetragona.*		*Enneagonum hyalinum.*		*Abylopsis eschscholtzii.*		*Bassia bassensis.*	
			P.	P.	P.		P.	P.	P.	P.	P.	P.	E.	E.	P.	E.	P.	E.	P.	E.	P.	E.
																						COARSE
8	24.viii.28	I.T.O.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	1
11	6.ix.28	I.T.O.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19*	20.x.28	O.T.O.	5	..	..	+	2	+	..	..	..	..	..	..	..	..	..	..	3	14	..	11
20	20.x.28	O.T.O.	..	..	..	+	..	..	..	..	..	..	..	..	..	..	..	..	..	2	4	2
21	22.x.28	3 m. E. night.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
26	19.xi.28	I.T.O.	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
28	23.xi.28	O.T.O.	..	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..
43	26.ii.29	C.B.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
44	27.ii.29	Li.I.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
45	28.ii.29	O.C.P.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19	..	..	..	..
46	28.ii.29	I.C.P.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
49	17.iii.29	I.P.P.	3	..	..	..	4	..	..	..	..	..	1	+	..	..	3	3	..	..	..	..
50	18.iii.29	O.P.P.	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
																						1-METRE
8	24.viii.28	I.T.O.	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	1	..
11	6.ix.28	I.T.O.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1
19	20.x.28	O.T.O.	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	..	3	8	8	..
21	22.x.28	3 m. E. night.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	18	..	..
26	19.xi.28	I.T.O.	..	..	..	..	..	..	..	+	..	..	..	..	..	..	..	..	..	..	..	..
28	23.xi.28	O.T.O.	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	3	5	5
29	24.xi.28	O.T.O. B.S.N.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
31	2.xii.28	3 m. E. B.S.N.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
43	26.ii.29	C.B.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
44	27.ii.29	Li.I.	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..	2	..	..	..	..
45	28.ii.29	O.C.P.	..	..	..	..	..	..	..	..	..	..	..	..	3	6	..	..	..	..	..	6
46	28.ii.29	I.C.P.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..
49	17.iii.29	I.P.P.	+	..	..	..	7	..	..	..	..	..	..	..	..	..	1	27	..	10	10	20
50 (i)	18.iii.29	O.P.P.	..	..	10	..	..	..	+	..	+	..	..	..	4	..	..	26	..	..	..	..
50(ii)	18.iii.29	O.P.P.	..	..	..	..	1	..	..	..	..	+	+	..	2	2	5	..	..	..	..	..

P. = Polygastric stage. E. = Eudoxid.

I.T.O., in Trinity Opening; O.T.O., outside Trinity Opening; C.B., off Cape Bedford; Li.I., off Lizard Island; O.C.P., outside Cook's Passage; I.C.P., inside Cook's Passage; I.P.P., inside Papuan Pass; O.P.P., outside Papuan Pass; B.S.N., bottom stramin net. St. 50 (i) = 400 m. St. 50 (ii) = 170 m. (For positions see Chart II, Vol. II, No. 1.)

that 3 miles East of Low Isles.

Galetta chuni.	*Galetta turgida.*	*Diphyes dispar.*		*Diphyes bojani.*		*Diphyes chamissonis.*		*Chelophyes appendiculata.*	*Chelophyes contorta.*	*Eudoxia russelli.*	*Eudoxoides mitra.*		*Eudoxoides spiralis.*		*Dimophyes arctica.*	*Lensia subtiloides.*	*Lensia subtilis.*	*Lensia campanella.*	*Lensia fowleri.*	*Lensia* spp.		Small, unidentified.	Station Number.
K.																							
P.	P.	P.	E.	P.	E.	P.	E.	P.	P.		P.	E.	P.	E.	E.	P.	P.	P.	P.	P.	E.		
..	..	..	1	..	..	9	30	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8
1	..	..	..	..	..	1	61	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11
+	+	9	30	6	16	..	..	12	5	4	..	3	..	..	..	..	+	1	..	11	3	86	19*
2	1	..	..	2	6	..	..	2	..	..	..	..	9	..	..	2	7	..	..	12	15	68	20
..	..	..	..	..	..	54	126	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1800	21
+	..	3	26	..	..	65	197	..	26	..	..	..	26	..	..	181	..	..	..	..	..	1400	26
..	..	..	..	..	9	..	..	..	2	..	..	..	..	..	+	..	10	..	+	1	..	85	28
..	..	..	..	..	..	17	85	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1400	43
..	..	..	..	..	..	12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	800	44
..	..	..	2	..	..	2	..	..	2	..	..	..	..	..	..	18	..	..	..	..	..	..	45
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	46
2	..	3	3	..	..	10	26	..	..	..	..	..	..	..	..	28	..	..	..	..	..	1194	49
+	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	50
RAMIN.																							
..	..	..	1	..	7	30	104	..	..	..	..	..	7	..	..	7	..	..	..	..	..	..	8
..	..	..	9	1	1	..	28	..	..	..	..	..	..	..	..	7	..	..	..	..	..	..	11
+	..	..	2	7	34	..	..	3	8	..	2	8	17	..	..	..	..	5	..	..	..	..	19
..	..	..	..	..	..	75	846	..	..	..	..	..	..	..	..	74	..	..	..	..	..	..	21
..	..	..	..	1	..	20	360	1	..	..	..	..	..	..	..	79	..	..	..	..	..	..	26
..	..	3	5	8	5	..	..	8	16	..	10	..	26	26	..	32	..	..	..	..	..	..	28
..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	29
..	..	..	..	..	..	536	166	..	..	..	..	..	..	..	..	128	..	..	..	..	..	..	31
..	..	..	..	..	..	14	268	..	..	..	..	..	..	..	..	60	..	..	..	..	..	..	43
..	..	..	..	..	..	105	36	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	44
..	..	3	..	..	..	7	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	45
..	..	1	..	..	..	30	41	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	46
+	..	..	1	..	10	40	70	..	1	..	..	..	+	..	..	20	..	1	..	..	..	342	49
+	..	..	..	..	..	7	31	..	..	..	..	..	+	..	..	31	..	..	..	..	..	..	50 (i)
3	+	..	..	2	..	6	32	..	3	..	2	..	..	..	..	17	..	1	..	+	..	..	50 (ii)

* St. 19, coarse silk, two hauls here combined together.

+ Implies that specimens were found only during examination of the remainder of the total catch from which the samples for counting been taken.

the deeper cooler layers. It is significant that the single specimen recorded here came from outside the barrier reef in the deepest haul taken during the expedition, when the net went down to a level at which the temperature was at least as cool as 12° C. This record fills in a wide gap in the known distribution of *D. arctica* in the Western Pacific.

The presence of *Lensia subtiloides*, which had up to now only been recorded from the collections of the "Siboga" Expedition, in such large numbers is interesting, especially as its period of greatest abundance occurs during the hottest time of the year. Actually the approximate lower limit of its abundance lies at about 25° C., and this may be an indication that this species is likely to be confined in its distribution to waters of this temperature and above, and therefore thrives in a narrower equatorial zone than do most of the other species of warm-water siphonophores.

Considering the very few collections that were made in the waters outside the barrier, the number of species recorded is quite high, and it is to be expected that a greater number of collections would have brought to light the presence of most of the commoner widely distributed warm-water siphonophores. Apart from the three species which exhibited apparent adaptability to coastal conditions, it is probable also that in other years the species recorded in the barrier reef lagoon during the period of high salinity might be different from those recorded here. The different species of siphonophores are probably distributed in swarms irregularly over the ocean waters, and their presence in the barrier reef lagoon would thus depend upon their chance occurrence near the openings in the reef through which they might invade the lagoon, or to their being carried at night by high tides over the tops of the outer reefs.

REFERENCES.

Bigelow, Henry B. 1911. The Siphonophorae. Rep. Sci. Res. Expedition to the eastern tropical Pacific . . . by the U.S. Fish Commission Steamer "Albatross". XXIII. Mem. Mus. Comp. Zool. Cambridge, Mass. XXXVIII, No. 2, pp. 173–402, 32 pls.

—— 1931. Siphonophorae from the Arcturus Oceanographic Expedition. Zoologica, Sci. Contrib. New York Zool. Soc. VIII, No. 11, pp. 525–592, 35 text illust.

Lens, Albertine D., and Van Riemsdijk, Thea. 1908. The Siphonophora of the "Siboga" Expedition. Siboga-Expeditie, IX, pp. 1–130, pls. i–xxiv, 52 text illust.

Moser, F. 1925. Die Siphonophoren der Deutschen Südpolar-Expedition, 1901–1903, zugleich eine neue Darstellung der ontogenetischen und phylogenetischen Entwickelung dieser Klasse. Deutsche Südpolar-Expedit. Bd. XVII, Zoologie, Bd. IX, pp. 1–541, pl. i–xxxiii, 61 text illust.

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THE ZOOPLANKTON

V. THE OCCURRENCE AND SEASONAL DISTRIBUTION OF THE MYSIDACEA AND EUPHAUSIACEA

BY

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WITH FIVE TEXT-FIGURES.

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THE OCCURRENCE AND SEASONAL DISTRIBUTION OF THE MYSIDACEA.

Twenty-three species of Mysidacea were found in the collections from the Barrier Reef. Of these, six occurred in the bottom stramin net at Stn. 29 (24.xi.28) in deep water outside the reef, and are bottom-living species. The remaining seventeen were caught in various plankton nets worked off the bottom and are therefore to be regarded as pelagic or planktonic species. It is the occurrence and distribution of these species which are dealt with here.

The pelagic Mysidacea play a very insignificant part in the plankton. The following table gives the percentage of the total animals formed by the Mysidacea for the different nets on the average for each month in the Barrier Reef Lagoon. It will be seen that at no time did Mysids form more than 0·4% of the total plankton in numbers, and were, when present, generally very many fewer than that. The percentage of the total animals in a haul formed by Mysids is consistently higher in the stramin nets than in either the coarse or fine nets, but the actual number of specimens caught was usually highest in the coarse nets.

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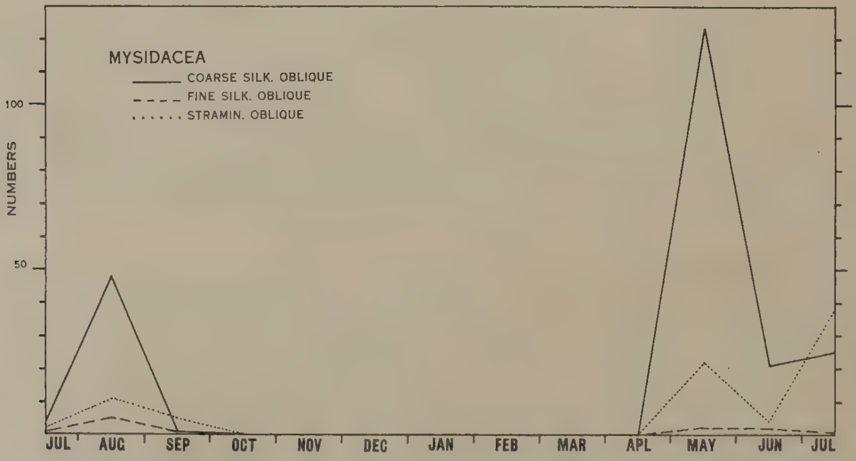
* Systematic accounts of these groups are given in a separate report (see Vol. V, No. 4).

Numbers of Mysidacea as a Percentage of the Total Animals Caught each Month.

	Oblique hauls.		
	Coarse silk.	Fine silk.	Stramin.
1928 :			
July	·002	·004	·06
August	·05	·008	·2
September	·002	·003	·07
October	+	—	—
November	—	—	+
December	—	—	—
1929 :			
January	—	—	—
February	—	—	—
March	—	—	—
April	—	—	—
May	·1	·005	·1
June	·03	·003	·08
July	·03	·002	·4
Average for year (based on average catch for each month)	·017	·002	·066*

* Excluding Echinoderm larvae.

In Text-fig. 1 are given the curves for the average catches for each month of all Mysidacea for all three nets. It brings out two important facts : (1) that Mysidacea were absent from the day plankton hauls at the weekly station 3 mi. E. of Low Island from



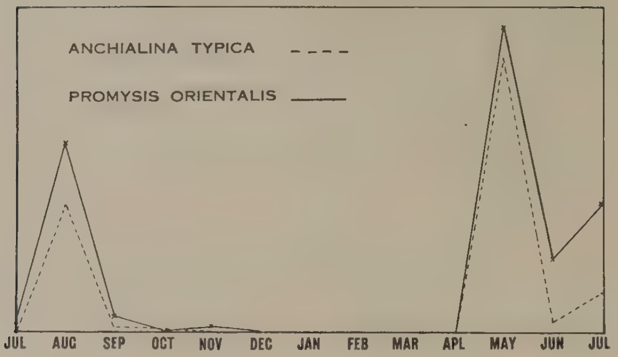
Text-fig. 1.—Curves showing the average catch of Mysids for each month at the position 3 miles east of Low Isles in the Barrier Reef Lagoon. (Coarse and fine silk, and stramin nets, oblique hauls.)

October to May, and (2) that Mysidacea were most abundant in August and May. An examination of the Mysidacea from these hauls shows that they were made up mainly of two species, *Anchialina typica* and *Promysis orientalis*. Six other species of Mysidacea occurred in these nets, but never more than one specimen in any one haul, and not more than two specimens altogether of any species. The following table shows the number of *Anchialina typica* and *Promysis orientalis* present in the hauls, and a note is added of the occurrence of the other species :

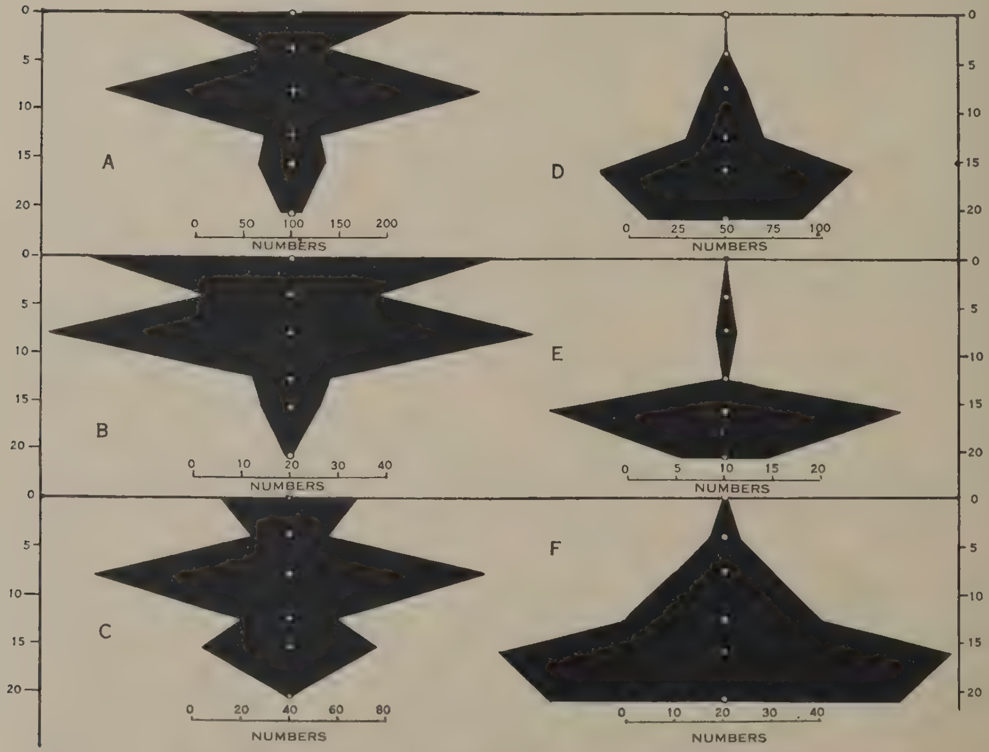
Station.		*Anchialina typica.*			*Promysis orientalis.*			Other species.
		C.	S.	F.	C.	S.	F.	
1	27.vii.28	0	0	0	7	3	1	1 *Hemisiriella parva.*
2	30.vii.28	0	0	0	0	2	0	1 *Siriella vulgaris.*
3	4.viii.28	0	1	0	11	0	1	..
5	11.viii.28	2	1	2	1	3	0	..
6	17.viii.28	2	9	0	24	36	11	..
7	22.viii.28	1	1	10	0	0	0	..
9	31.viii.28	100	0	0	100	6	0	..
10	4.ix.28	0	3	0	2	5	1	..
12	11.ix.28	0	0	0	3	1	0	..
13	20.ix.28	0	0	0	0	3	0	..
15	2.x.28	1	0	0	0	0	0	..
27	21.xi.28	0	0	0	0	0	0	1 *Siriella thompsoni.*
57	18.v.29	0	0	0	3	3	0	..
58	25.v.29	212	54	1	248	27	2	..
59	31.v.29	8	4	2	22	2	3	1 *Doxomysis littoralis.*
60	7.vi.29	0	0	0	0	4	0	..
61	14.vi.29	0	0	0	35	7	4	..
63	24.vi.29	8	0	1	20	1	2	1 each of *Siriella vulgaris, Doxomysis littoralis* and *Anisomysis laticauda.*
64	5.vii.29	0	30	2	0	24	2	..
66	11.vii.29	0	0	0	41	25	1	..
67	17.vii.29	1	9	0	8	26	1	1 *Anchialina grossa.*

In Text-fig. 2 the average catches for all nets combined of the two species, *Anchialina typica* and *Promysis orientalis*, at the position 3 mi. E. of Low Isles are shown separately. The curves follow closely those of Text-fig. 1, and show that the occurrence of each of these species throughout the year follows a closely similar course. *P. orientalis* is slightly more abundant than *A. typica*, but otherwise the two curves are strikingly parallel.

The large number of specimens of *Anchialina typica* and *Promysis orientalis* in the coarse nets from Stn. 9 (31.viii.29) and Stn. 58 (25.v.29) is worthy of note. These hauls are responsible mainly for the maxima of the curves in Text-figs. 1 and 2. The mysids at both these stations were largely young, and immature specimens and the high numbers are probably due to a sudden accession of recently hatched young to the plankton.



Text-fig. 2.—Curves showing the average catches of *Anchialina typica* and *Promysis orientalis* for each month at the position 3 miles east of Low Isles in the Barrier Reef Lagoon. (Coarse and fine silk, and stramin nets, oblique hauls combined.)



Text-fig. 3.—The vertical distribution of Mysids. A, B, C, At night; Stn. 65 (10.vii.29), 9 p.m to 11.25 p.m. A = All mysids; B = *Anchialina typica*; C = *Promysis orientalis*. D, E, F. By daylight; Stn. 62 (15.vi.29), 11.20 a.m. to 1.45 p.m. D = All mysids; E = *Anchialina typica*; F = *Promysis orientalis*. The circles and white dots indicate the average depths at which the hauls were made. All coarse silk townets.

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Vertical Distribution.

The collections at Stn. 62 and Stn. 65 provide interesting data on the possible daily movements of Mysidacea. The details for each of these stations are given below :

Station 62 (15.vi.29). *Daylight.*

Average depth.	Total Mysids.	*Anchialina typica.*	*Promysis orientalis.*	Other species.
S.	0	0	0	0
4·0	1	1	0	0
7·5	20	1	19	0
12·5	41	0	41	0
16·0	130	36	94	0
21·0	80	9	70	1 *Hemisiriella pulchra.*

These results are expressed in graphic form in Text-fig. 3, D, E, F, and show that during daylight the Mysidacea were concentrated in the deeper water. They show a maximum at about 16 metres, and disappear almost completely from the upper 4 metres. The two species which form the daylight Mysidacean fauna behave in almost identical manner, *P. orientalis,* however, being less markedly aggregated in the deeper water, and extending upwards to about 4 metres, though in diminishing numbers.

The results from this station also bear out in a striking manner the results from the coarse, stramin and silk nets, in that the Mysidacea caught belonged to two species only, *A. typica* and *P. orientalis*, one solitary specimen of *Hemisiriella pulchra* being the only other Mysid taken in this series of hauls.

The details of Stn. 65 present a very different picture :

Station 65 (10.vii.29). *Night.*

Average depth.	Total Mysids.	*Anchialina typica.*	*Promysis orientalis.*	*Hemisiriella pulchra.*	*Siriella dubia.*	*Gastrosaccus* sp.	*Hypererythrops spinifera.*	*Doxomysis littoralis.*	*Anisomysis incisa.*	*Anisomysis laticauda.*
S.	234	84	26	104	12	4	0	4	0	0
3·7	71	35	14	17	3	0	0	2	0	0
8·0	390	100	82	165	9	0	0	30	0	4
12·5	61	15	18	25	1	0	0	1	1	0
15·5	70	13	35	16	0	0	0	4	0	2
20·7	18	0	4	9	0	0	2	3	0	0

These results are expressed graphically in Text-fig. 3, A, B, C, for comparison with those from Stn. 62. They show quite definitely that at night the Mysidacean fauna was distinctly nearer the surface, with a maximum at 8 metres, and the greater part of the Mysid population between 8 metres and the surface. Taking the Mysids as a whole, and the two species, *A. typica* and *P. orientalis*, which occur in the plankton by day as well as by night, Text-fig. 3 demonstrates diurnal movement in these forms.

It will be seen from Text-fig. 3 that the proportion of specimens of *A. typica* at the surface at night is considerably greater than in *P. orientalis*. Russell (1925 and 1931) has noted a similar difference in the behaviour of *Anchialina agilis* compared with other Mysids, chiefly *Leptomysis gracilis*. He observes, " Unlike the other Mysids, which never rose much above 20 metres from the bottom, this form exhibited a very sudden migration towards midnight right to the surface ", and he attributes the difference in behaviour to a difference in activity. In the present case *P. orientalis* does actually reach the surface, but in proportionally smaller numbers than *A. typica*.

Diurnal migrations have been shown to take place in many species of Mysidae. Fage (1933), however, has brought forward considerable evidence to show that diurnal migrations are governed by the breeding seasons of the species, daily movements being much more marked during the period of sexual activity than at other times of the year. It is to be noted that the period of the year from May to October, when Mysids are present in the day townettings, coincides with the breeding season of the two species concerned. Ovigerous females of both species were present in the plankton from July to September, 1928, and from May to July, 1929, and the number of immature specimens present suggests that active reproduction was going on during those periods. It is to be presumed that from October to May, when Mysids are absent from the day townettings, is the non-breeding season. What happens to *Anchialina typica* and *Promysis orientalis* during this period ? The collection provides no information on this point. I would venture to suggest that both species migrate to offshore waters when not breeding, and migrate back again

Station* . .	..	21	21	..	..	..	..	65	Occurrences in daylight hauls.
Date . .	1.x.28	22.x.28	22.x.28	16.xi.28	28.xi.28	23.v.29	28.vi.29	10.vii.29	
Time . .	7.55 p.m.	8 p.m.	8 p.m.	..	..	..	..	..	
Net . .	S.C.N.	C.S.	1 m. Str.	..	C.S.	..	..	..	
Depth . .	..	..	..	..	Surface	..	..	..	
Siriella thompsoni .	..	..	..	1	..	..	..	..	Stn. 16, 1 ; Stn. 27, 1.
,, *nodosa* .	2	..	..	2	..	..	3	..	None.
,, *vulgaris* .	7	..	..	5	4	3	1	..	Stn. 2, 1 ; Stn. 63, 1.
,, *inornata* .	3	..	..	3	6	5	6	..	None.
,, *anomala* .	..	..	..	..	..	..	1	..	,,
,, *dubia* .	..	..	..	..	..	..	..	25	,,
Hemisiriella pulchra .	..	..	1	..	..	..	..	336	Stn. 62, 1.
,, *parva* .	..	..	..	..	..	..	..	..	Stn. 1, 1.
Anchialina typica .	..	2	9	3	..	..	1	247	..
,, *grossa* .	..	..	..	..	..	..	1	..	Stn. 67, 1.
Gastrosaccus sp. .	..	..	..	1	1	3	..	4	None.
Pseudanchialina pusilla .	..	..	..	20	50	..	..	..	,,
Hypererythrops spinifera .	..	..	..	..	..	..	..	2	,,
Promysis orientalis .	..	..	2	..	..	..	2	179	..
Doxomysis littoralis .	..	..	..	..	..	..	1	44	Stn. 59, 1 ; Stn. 63, 1.
Anisomysis laticauda .	..	..	..	..	..	..	..	6	Stn. 63, 1.
,, *incisa* .	..	..	..	22	..	..	..	1	None.

* The bottom stramin net at Stn. 29 (24.xi.28) captured the following species of Mysidacea : *Rhopalophthalmus egregius*, Hansen, *Metamblyops stephensoni*, Tattersall, *Hypererythrops spinifera* (Hansen), *Synerythrops indica*, Hansen, *Katerythrops* sp., and *Pseudomysidetes russelli*, Tattersall. There were none of the species found in the plankton hauls, and from their structure they are all bottom-living species.

to shallow water for reproduction. If this should eventually prove to be the case, there is an annual migratory cycle.

The results from Stn. 65 also demonstrate another interesting point, namely, that the normal daylight population of Mysids is augmented during darkness by other species, which are either completely absent during the day or at most occur in ones and twos. During the daytime these extra species are presumably living actually on the bottom, buried in sand or mud, and become pelagic only during darkness.

In addition to the Mysids from Stn. 65, there are in the collection a number of tubes of specimens from other night hauls, mainly from the reef lagoon and the reef flats. These also contain species not found in day hauls, or only represented by occasional specimens. In the table (p. 282) I give a complete list of the species from these townettings, and have added a note on the occurrence of any of them in day nets. The table bears out completely the results from Stn. 65. It will be noted that out of seventeen species caught in night hauls, eight were not found at all in any of the day nets, and seven others were represented in day townettings by odd specimens on one or two occasions. The difference between the day and night Mysid fauna is strikingly brought out.

GEOGRAPHICAL DISTRIBUTION OF THE BARRIER REEF MYSIDACEA.

The following table summarizes the geographical distribution of all the Mysidacea in the collection. It demonstrates quite clearly that the Mysidacea of the Barrier Reef form part of a more or less uniform shallow water tropical fauna extending from the Indian Ocean and the Bay of Bengal across to the China Sea and the western part of the Pacific at least. Fifteen of the Barrier Reef species were captured by the "Siboga" in the seas of the East Indies, and of these eight have been recorded from India. Only two species, *Siriella thompsoni* and *Anchialina typica*, have a distribution which extends outside the area defined above, and both these forms are world-wide in their occurrence in the tropical and subtropical waters of the world.

Barrier Reef.	Siboga.	India.	Other distribution.
Siriella thompsoni	×	—	World-wide tropical and subtropical.
S. nodosa	×	—	..
S. vulgaris	×	×	Arabian Sea; Queensland.
S. inornata	×	—	Queensland.
S. anomala	×	—	..
S. dubia	×	×	Torres Straits.
Hemisiriella pulchra	×	—	..
H. parva	×	×	Bay of Bengal; Java; Malaysia.
Anchialina typica	×	×	World-wide tropical and subtropical.
A. grossa	×	×	Bay of Bengal; Gulf of Siam; Gilbert Is.
Pseudanchialina pusilla	×	—	Bay of Bengal; Celebes.
Hypererythrops spinifera	×	×	..
Promysis orientalis	×	—	China Seas; Ceylon to New Guinea.
Doxomysis littoralis	—	×	..
Anisomysis laticauda	×	—	..
A. incisa	..	..	..
Rhopalophthalmus egregius	×	×	Japan; Australasia.

The occurrence of *Siriella thompsoni* three times within the Barrier Reef Lagoon is of some interest. One specimen of this species was taken on each occasion at Stn. 16 (3.xi.28), in a night townetting on 16.xi.28, and at Stn. 27 (21.xi.28). The species is an oceanic form, and its capture in the lagoon is evidence of an incursion of oceanic species into the lagoon at this period. Further evidence in support of this is provided by the occurrence of oceanic species of Euphausians in the lagoon between July and October, 1928 (see below, p. 286).

With the exception of *Siriella thompsoni* the species of Mysidacea taken by the Barrier Reef Expedition are neritic forms, that is, species normally living in shallow coastal waters within the 100-fathom line. *Anchialina typica* appears occasionally to frequent more or less open oceanic waters, though most of the records are from shallow coastal waters.

SUMMARY.

1. Mysidacea play an insignificant part in the plankton of the Barrier Reef region.
2. During the hours of daylight Mysidacea are absent from the plankton from October to May.
3. From May to September the Mysidacea in the day plankton belong almost entirely to two species, *Anchialina typica* and *Promysis orientalis*. Occasional specimens of other species are met with.
4. These two species have a closely similar seasonal distribution, showing maxima in May and August.
5. They exhibit diurnal vertical movements, being found in the deeper layers by day and rising to the surface by night.
6. At night the day population of Mysids in the plankton is augmented by numerous species, which are apparently bottom-living by day and become planktonic at night.
7. The fauna of the Barrier Reef region, as far as Mysids are concerned, is part of a widely distributed shallow-water tropical fauna, extending from India in the west to the China Seas and the western Pacific in the east.
8. The occurrence of *Siriella thompsoni* in the Barrier Reef Lagoon in November, 1928, is evidence of an incursion of oceanic species into the lagoon at this period.
9. The Mysidacea of the Barrier Reef region are, with the exception of *Siriella thompsoni*, neritic species.

OCCURRENCE AND SEASONAL DISTRIBUTION OF THE EUPHAUSIACEA.

Ecologically the Euphausiacea can be divided into two main groups of species—oceanic and coastal. The majority of the Order belong to the oceanic group, but the genera *Nyctiphanes* and *Pseudeuphausia* are essentially coastal forms. In the Barrier Reef region it was to be expected that any Euphausians which occurred there would belong mainly to the coastal group, and this has proved to be the case. The dominant species, and, in fact, almost the only one to occur in the lagoon and on the reef flats is *Pseudeuphausia latifrons*.

Euphausians did not form a very important part of the plankton catches on the Barrier Reef. The table which follows gives the numbers of Euphausians expressed as a percentage of the total animals caught in each month by the three nets, coarse and fine silk, and stramin :

Numbers of Euphausiacea as a Percentage of the Total Animals Caught each Month.

	Oblique hauls.		
1928 :	Coarse silk.	Fine silk.	Stramin.
July	3·62	1·64	·35
August	·33	·03	·35
September	2·64	·36	·77
October	1·20	·18	·65
November	1·09	·16	·08
December	·09	+	·03
1929 :			
January	·31	..	..
February	·46	..	..
March*	..	..	..
April*	+	+	·01
May	·01	+	·03
June	·05	+	1·14
July	..	+	·47
Average for year (based on average catch for each month)	0·78	0·14	0·19†

* In the months of March and April large numbers of Euphausiacean larvae are shown in the Tables for the coarse and fine silk net catches in Vol. II, No. 6. The majority of these were Protozoea larvae of Sergestids. These had been correctly identified in the original notebooks by Mr. J. S. Colman, but subsequently, owing to a misunderstanding, they were transferred to Euphausiacea.

The corrected figures should read as follows for Euphausiacean larvae in Vol. II, No. 6 :

Table II, p. 186. *Coarse silk :*

Stn. 48	15.iii.29	..
,, 51	25.iii.29	..
,, 52	6.iv.29	..
,, 53	13.iv.29	20
,, 54	20.iv.29	..
,, 55	26.iv.29	..

Table IV, p. 190. *Fine silk :*

Stn. 53	13.iv.29	..
,, 54	20.iv.29	..

Correspondingly, in Table IX, p. 198, they should read—

Coarse silk :

March, 1929	..
April, 1929	5

Fine silk :

April, 1929	..

Similarly, in Table VI, p. 194, the revised figures should read as follows :

Coarse silk :

Stn. 43	26.ii.29	..
,, 44	27.ii.29	..
,, 45	28.ii.29	..
,, 49	17.iii.29	20
,, 50	18.iii.29	..

Stramin :

Stn. 44	27.ii.29	..

Fine silk :

Stn. 43	26.ii.29	..
,, 44	27.ii.29	..

The figures for Protozoea will have to be transferred when the report on Decapoda is written.

F. S. Russell.

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† Excluding Echinoderm larvae.

The dominant species at the weekly station, 3 miles east of Low Isles, was *Pseudeuphausia latifrons*, which was present practically all the year round. Four other species occurred at this station, but only in very small numbers, and only from the end of July, 1928, to the middle of October, 1928. These four species and their occurrences were :

Thysanopoda tricuspidata : Stns. 2, 3, 7, 9, 10, 12, 13, 14, 15, 18, 21.
Euphausia tenera : Stns. 7, 9, 10, 13, 14, 15, 16.
Nematoscelis microps : Stn. 13.
Stylocheiron carinatum : Stns. 12, 16.

From the end of October, 1928, to the conclusion of the Expedition no other species of Euphausian, except *Pseudeuphausia latifrons*, was detected in the reef and lagoon townettings. I am unable to offer any explanation of this curious fact. Other species were present in the waters outside the reef, as the following table shows, but none of them penetrated into the Barrier Reef Lagoon and reef flat except at the period mentioned above. Mr. Russell tells me that evidence is accumulating from other groups of animals that a number of oceanic species were present in the Barrier Reef Lagoon at the beginning of the Expedition's year, August–October, 1928. The hydrographical results do not suggest any incursion of oceanic water at this time, but, from whatever cause, there can be no doubt that an incursion of oceanic Euphausians into the Barrier Reef Lagoon did take place at this period. In this table the stations are arranged in order of depth, and the species in the order in which they appeared at the stations. It will be noted that, out of fourteen species of Euphausiacea represented in the collection, no fewer than nine were taken only at stations outside the reef and never penetrated into the lagoon and reef flat at all. On the other hand, *P. latifrons* became scarcer as the water deepened

Table Showing Species of Euphausiacea Captured Outside the Barrier Reef Lagoon and the Stations at which they were Taken.

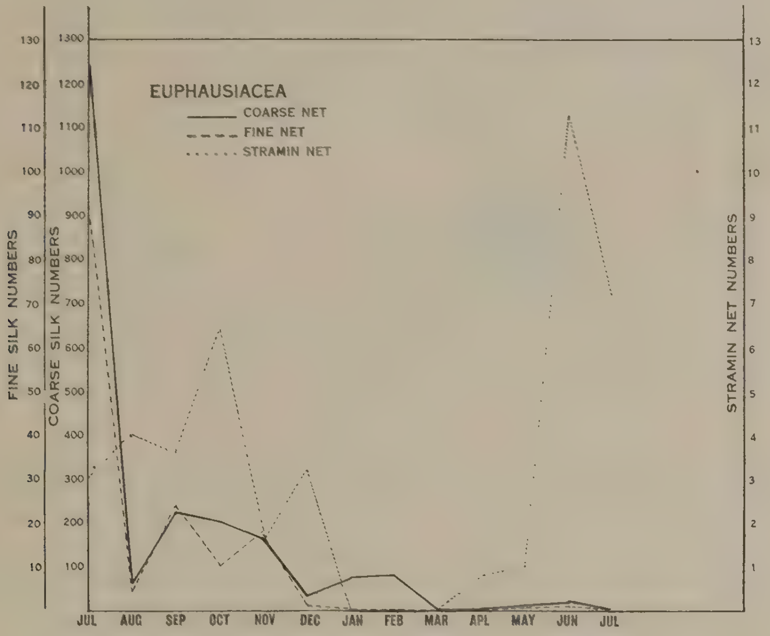
Station.	Date.	Locality.	Depth (metres).	Net.	*Pseudeuphausia latifrons.*	*Thysanopoda tricuspidata.*	*Euphausia tenera.*	*Nemetoscelis microps.*	*Stylocheiron carinatum.*	*Stylocheiron suhmii.*	*Stylocheiron abbreviatum.*	*Stylocheiron elongatum.*	*Euphausia siboga.*	*Stylocheiron affine.*	*Euphausia diomedeae.*	*Euphausia mutica.*	*Euphausia pseudogibba.*	*Thysanopoda orientalis.*	Other forms present.
43	26.ii.29	C.B.	30	S.	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
44	27.ii.29	Li.I.	31	S.	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	24.viii.28	I.T.O.	45	C.S.	128	10	3	2	..	..	..	..	..	..	..	..	..	..	..
				S.	65	..	2	2	..	..	..	..	..	..	..	..	..	..	..
49	17.iii.29	I.P.P.	46	C.S.	27	..	..	..	..	..	..	..	..	..	..	..	..	..	..
				S.	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..
26	19.xi.28	I.T.O.	57	C.S.	620	..	..	..	..	..	..	..	..	..	..	..	..	..	..
				S.	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..
11	6.ix.28	I.T.O.	61	C.S.	1094	..	..	..	..	..	..	..	..	..	..	..	..	..	..
				S.	115	2	..	..	..	..	..	..	..	..	..	..	..	..	..
19	20.x.28	O.T.O.	225	C.S.	88	29	4	4	25	5	2	..	..	..	..	..	..	..	..
				S.	18	2	3	3	6	5	2	..	..	..	..	..	..	..	..
50	18.iii.29	O.P.P.	400	S.	2	..	..	..	..	4	2	2	4	..	..	..	..	..	..
20	20.x.28	O.T.O.	600	C.S.	..	3	..	3	5	8	5	..	..	5	..	..	..	..	*Thysanopoda* juv. 3. *Euphausia* juv. 3.
28	23.xi.28	O.T.O.	600	C.S.	..	..	2	..	..	4	..	..	..	..	2	6	..	..	*Thysanopoda* juv. 2.
				S.	..	..	8	2	..	..	..	..	..	..	8	12	4	..	*Euphausia* juv. 3.
45	28.ii.29	O.C.P.	600	S.	..	..	..	3	..	..	..	..	..	..	..	..	3	3	..

C.B., off Cape Bedford ; Li.I., off Lizard Island ; I.T.O., inside Trinity Opening ; I.P.P., inside Papuan Pass ; O.T.O., outside Trinity Opening ; O.P.P., outside Papuan Pass ; O.C.P., outside Cook Passage.

and at the deep water stations 20, 28 and 45 was absent altogether. The four other species which penetrated into the lagoon are all upper water species, characteristic of the upper 100 metres of oceanic waters.

Pseudeuphausia latifrons (G. O. Sars).

The following curves (Text-fig. 4) show the occurrence of this species month by month in the three series of townettings with coarse, stramin and fine nets. The figures are taken from Table IX (Russell and Colman, 1934), and represent all the Euphausians taken in these nets.



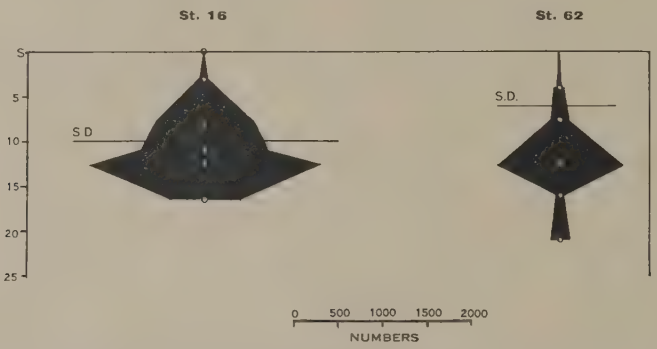
Text-fig. 4.—Curves showing the average catch of Euphausians for each month at the position 3 miles east of Low Isles in the Barrier Reef Lagoon. All oblique hauls. A = Coarse silk; B = fine silk; C = stramin net.

As I have pointed out above, four other species of Euphausians, in addition to *P. latifrons*, are represented in these townettings, but the numbers of the other species are so small that, for all practical purposes, the figures may be taken to represent the occurrence of *P. latifrons* alone. The high numbers for July are due to the large number of Calyptopis stages and early Furcilias present in the gatherings at that time.

From July, 1928, to November, 1928, larval stages of all kinds from the Calyptopis to the Cyrtopia were present. After the end of November only late Furcilia (stages 13 and 14) and Cyrtopia stages and young adults occurred in the townettings. The total numbers dropped and remained low for the rest of the year during which observations were carried on.

From an examination of the townettings it would appear that the breeding season of this species is mainly between July and November. Ovigerous females were found in townettings taken in November, 1928, and March, 1929. Since Calyptopis larvae were found at the end of November, the ovigerous females found earlier in that month may be taken to represent the last of the breeding females of the season. Those captured in March I take to be the early breeding females of the next season, which would be ready to liberate Calyptopis larvae in June and July. Unfortunately there is no evidence from the material examined of Calyptopis larvae in the period May to July, 1929.

The numbers of Euphausians of all kinds fell very much in the months May to July, 1929, and, at the time when observations ceased, there were no signs of the onset of a new breeding season. It is interesting to observe that the ovigerous females were found at Stns. 23, 26 and 49. The first of these is the usual weekly station, 3 miles E. of Low Isles, but the other two are inside Trinity Opening and inside Papuan Pass respectively, where the water is from 46–57 metres in depth.



TEXT-FIG. 5.—The vertical distribution of *Pseudeuphausia latifrons* at two stations in daylight. Stn. 16 (3.x.28), 10.13 a.m. to 12.27 p.m.; Stn. 62 (15.vi.29), 11.20 to 1.45. p.m. The circles and white dots indicate the average depths at which hauls were made. All coarse silk townets.

There is, unfortunately, only slight information on the vertical distribution of *P. latifrons*. The diagrams (Text-fig. 5) show the distribution of this species, according to depth, at two stations in daylight. Both diagrams agree in showing the maximum concentration at 12·5 metres, but this concentration is much more marked at Stn. 62 than at Stn. 16, where considerable numbers occurred at 11 metres and 8 metres. There is no comparable evidence of the distribution of the species by night. At Stn. 65, taken only a month later than Stn. 62, the number of Euphausians in the nets was practically negligible.

GEOGRAPHICAL DISTRIBUTION OF THE BARRIER REEF EUPHAUSIANS.

All the species of Euphausians in the Barrier Reef collection are tropical and subtropical species. There are no temperate species present. Twelve of the fourteen species are found on all three oceans—Atlantic, Pacific and Indian. The exceptions are *Pseudeuphausia latifrons*, which is confined to the Pacific and Indian Oceans, and *Euphausia sibogae*, known only from the Pacific.

With the exception of *Pseudeuphausia latifrons*, a coastal species, all the others are oceanic forms and characteristic of the upper layers of the oceanic water. No fewer than twelve of the fourteen species were found in the Siboga collections.

SUMMARY.

1. Euphausians play only an insignificant part in the plankton of the Barrier Reef region.

2. The dominant species (and for all practical purposes the only one) of the region is *Pseudeuphausia latifrons* (G. O. Sars).

3. From July to October, 1928, four other species (oceanic forms) penetrated into the lagoon area in small numbers. After that period *P. latifrons* was the only species found there, though other species were present outside the reef.

4. The breeding season of *P. latifrons* appears to be from July to November, and this accounts for the greater numbers in the plankton at this time.

5. *P. latifrons* appears to avoid the surface layers by daylight.

6. The fauna of the Barrier Reef region as far as Euphausians are concerned consists, apart from *P. latifrons*, of widely distributed tropical and subtropical oceanic species. No temperate forms were present. *P. latifrons* is a coastal species with a wide distribution in the Indian and Pacific Oceans.

REFERENCES.

FAGE, L. 1933. Pêches planctoniques à la lumière effectuées à Banyuls-sur-Mer et à Concarneau. III : Crustacés. Arch. Zool. Exper. Gen. LXXVI, pp. 105–248, text-figs. 1–14.

RUSSELL, F. S. 1925. The Vertical Distribution of Marine Macroplankton : An Observation on Diurnal Change. J. Mar. Biol. Ass. U.K., N.S. XIII, pp. 769–809, 1 pl., text-figs. 1–6.

—— 1931. The Vertical Distribution of Marine Macroplankton. XI : Further Observations on Diurnal Changes. J. Mar. Biol. Ass. U.K., N.S. XVII, pp. 767–784, text-figs. 1–7.

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THE SEASONAL AND VERTICAL DISTRIBUTION OF THE COPEPODA

BY

G. P. FARRAN, B.A.

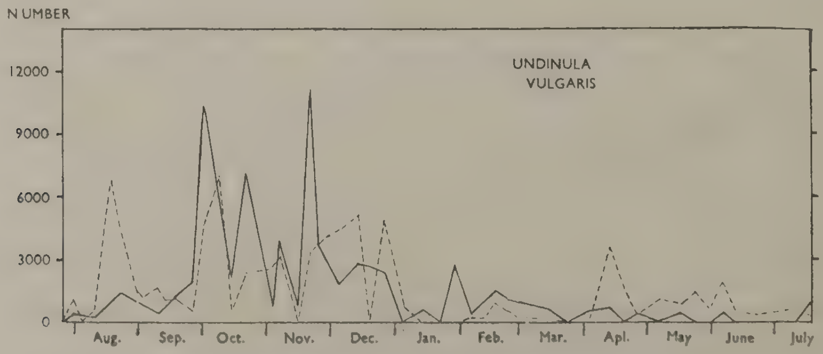
IN my previous report on the Copepoda of the Great Barrier Reef (Vol. V, No. 3, 1936), written mainly from a systematic standpoint, a list was given of the species whose habitat was (*a*) outside the reef, (*b*) in the reef passages, and (*c*) inside the reef at 3 miles east of Low Island, the headquarters of the Expedition. The present paper treats only of those species which occurred normally at 3 miles east, and gives a summarized account of their numerical distribution throughout the year as shown by the Coarse Silk and Stramin net oblique hauls, referred to in the following pages as C.S. and Stramin nets, and of their vertical distribution as shown by the four stations at which serial hauls at successive depths were made with the C.S. net. Though much larger samples were available from most of the stations than were used in the preparation of the first paper, only one additional species now falls to be recorded, viz. *Pseudodiaptomus aurivillii* Cleve, taken on a single station.

The total numbers of Copepoda on each station given by Russell and Colman in their account of the Composition of the Zooplankton (Vol. II, No. 6, 1934, pp. 186 and 188) have here been accepted as authoritative, the numbers of the separate species on each station being obtained by dividing Russell and Colman's totals in the proportions found in the composition of the samples examined and counted. The samples usually numbered from 100 to 400 specimens and amounted to $\frac{1}{50}$ to $\frac{1}{300}$ of the total catch, consequently when a species was only represented by two or three specimens in a sample, the estimate of the total number in a gathering cannot be considered as more than a broad approximation. Even if the whole of every gathering could have been counted it is quite evident that the results of individual hauls would have been far from giving more than an approximate numerical picture of the seasonal distribution. Russell and Colman have called attention to what is probably one of the reasons for this, mainly the downward movement of the copepod plankton in response to changes in light intensity and clearness of water. The collective total of all species of Copepoda in the C.S. net hauls on each station has been shown by them to follow fairly closely in many cases the variation in the maximum depth at which the Secchi disc was visible on the station. As the maximum depths to which the nets, both coarse silk oblique and stramin, were fished did not usually exceed 22 to 24 m. over a total depth of 31 to 32 m. this was perhaps to be expected. It might be thought that it would be easy to apply a correction to the catches of separate species which would reduce the error due to phototropic migration, but after several essays the attempt to do this was abandoned, for though a response to light intensity could sometimes be recognized in the graphs of abundance of many of the individual species, it was much less clearly marked than when the total catch of copepods was considered. The variation from station to station was in many cases clearly due to some other cause, possibly to a shoaling habit. The presence of other organisms, especially salps, medusae and oikopleura houses, which were sometimes very noticeable in the samples which I examined, may have had an adverse effect by reducing the quantity of water filtered, and it is not improbable that the oikopleura houses may, on the other hand, have increased the catch of very small species of which only a proportion are retained by the meshes of the net, by themselves acting as collectors, at any rate a large proportion of such species as *Oithona* and *Oncaea* were always found entangled in them.

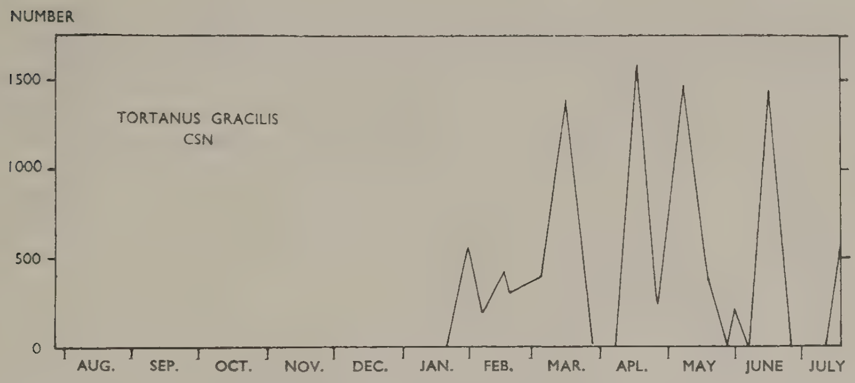
But even taking these other causes into account, the probability must be kept in mind that for some light-sensitive species, such as *Oncaea clevei*, the catches in the months in which the Secchi disc limit was deepest may not be fully representative of the numbers present. The following are the average depths for each month at which the Secchi disc became invisible, and these figures can if desired by employed as a basis for a correction of the graphs here given by the use of the factors which Russell and Colman (*l.c.*, Vol. II, No. 2, pp. 20–22) have worked out as the effect of light on the total catch, though such a correction would not, in most cases, materially alter the result.

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July
Meters .	8·4	14·7	11·7	13·1	16·0	14·6	21·3	8·0	10·7	7·6	8·1	7·6

In the following account the graphs illustrating the distribution throughout the year for each species are based on the average monthly catch made by the three or four monthly hauls, and are shown as percentages of the total annual catch of the species. These totals are given in Table I. Graphs to illustrate the wide variation in numbers from station to station are given for two species, *Undinula vulgaris* and *Tortanus gracilis* (Text-figs. 1 and 2). This type of distribution is found in most of the species making up the collection and shows that the monthly averages are statistically rather unreliable. In spite of this the general impression produced by the graphs is that for most species



TEXT-FIG. 1.—The catches of *Undinula vulgaris* by oblique hauls with the coarse silk (whole line) and stramin (dotted line) nets on each station at 3 mi. E. of Low Is.



TEXT-FIG. 2.—The catches of *Tortanus gracilis* by oblique hauls with the coarse silk net on each station at 3 mi. E. of Low Is.

there is a definite annual variation in numbers, which can presumably be put down to the influence of the annual variation in temperature salinity and sunlight on the life cycle.

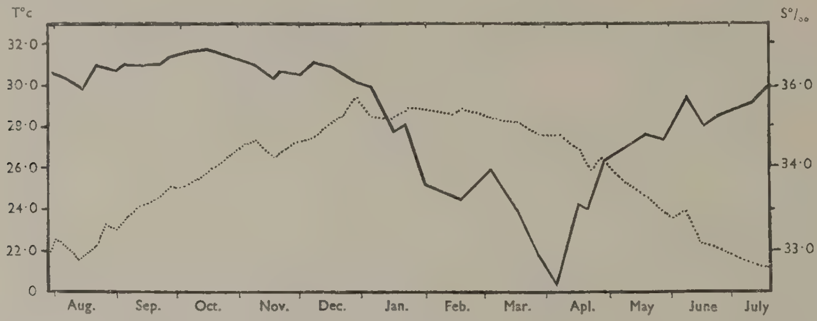
TABLE I.—*Most Frequent Species occurring at 3 mi. E. of Low Island, in order of abundance, with estimated total numbers of specimens taken in the C.S. oblique net during the year* 1928/29.

1.	*Paracalanus aculeatus*	881,500
2.	*Oithona plumifera*	431,330
3.	*Oncaea clevei*	347,710
4.	*Calanus pauper*	266,270
5.	*Paracalanus parvus*	239,000
5*a*.	*Acrocalanus longicornis* *Acrocalanus gibber* *Acrocalanus gracilis*	*148,430
6.	*Eucalanus subcrassus*	112,670
7.	*Corycaeus erythraeus*	101,580
8.	*Undinula vulgaris*	75,590
9.	*Calanopia elliptica*	37,140
10.	*Corycaeus catus*	35,430
11.	*Corycaeus asiaticus*	29,970
12.	*Centropages orsinii*	29,721
13.	*Euchaeta concinna*	28,040
14.	*Corycaeus lubbocki*	26,030
15.	*Centropages furcatus*	21,450
16.	*Acartia australis*	17,920
17.	*Setella gracilis*	17,000
18.	*Temora discaudata*	15,720
19.	*Clausocalanus furcatus*	14,070
20.	*Calanopia aurivilli*	12,960
21.	*Candacia discaudata*	12,140
22.	*Clausocalanus arcuicornis*	11,890
23.	*Tortanus gracilis*	10,290
24.	*Acartia pacifica*	9,030
25.	*Temora turbinata*	7,830
26.	*Labidocera minuta*	6,590
27.	*Acartia negligens*	4,310
28.	*Labidocera acuta*	2,990

* Combined total.

The figures for the month of July are a combination of those found at the beginning and the end of the Expedition, whose investigations began on 27th July, 1928, and ended on 17th July, 1929.

The salinity at 3 m. East, at a depth of 10 metres, showed a gradual fall from S‰ 35·41 on 5th April to S‰ 32·55 on 18th October, followed by an abrupt rise, the lessened salinity being due, as Mr. Russell informs me, to the heavy rainfall. The temperature range at 10 m. on the other hand, was relatively small, from 21·27° C. on 17th July, to 29·43° on 27th December, and showed a regular annual oscillation comparable to though about 10° higher than that to be found at the mouth of the English Channel. The actual temperatures and salinities on each station are given in Vol. II, No. 2 of the Report of the Expedition, and for convenience of reference a graph of them is here given (Text-fig. 3). The length of sunlit day at 15° S. latitude varies from about 13 hours in summer to 11 hours in winter.



Text-fig. 3.—Temperature (dotted line) and Salinity (unbroken line) at a depth of 10 m. 3 mi. E. of Low Isles.

It is probable that the connection between the annual variations in numbers of the copepods and meteorological changes is, in many cases, indirect, depending on the development of their appropriate foodstuffs or on the numbers of predatory organisms for which they might furnish food. Though there was no month in the year in which one or more species of copepod were not abundant or were absent, it may be said, taking a general view, that most species were abundant in February, March or April, and were scarce in August, September or October, though two of the most numerous species, *Paracalanus parvus* and *Oithona plumifera*, had their maxima in August and July respectively.

Vertical Distribution.

Horizontal hauls with the coarse silk net at the surface and five successive depths were made on four stations at 3 mi. East, three by day (Stns. 16, 62 and 68), and one by night (Stn. 65). Though large numbers of species, from 30 to 51, were taken on these stations, most of them were represented by very few specimens and did not furnish data sufficient to throw any light on their vertical distribution. Particulars of those species which were adequately represented are given in diagrammatic form as the percentages at each depth of the sum of the numbers taken in all the successive hauls on the station (Text-figs. 14–17). The depth at which the Secchi disc became invisible is shown as a horizontal line. These diagrams are only valid on the assumption that the vertical and horizontal distribution remained constant during the progress of the hauls, which occupied about $2\frac{1}{4}$ hours. The figure given under each species diagram is the estimated total number of specimens present in all the hauls of a series, but the percentages are calculated from the numbers present in the much smaller samples which were examined, from $\frac{1}{10}$ to $\frac{1}{50}$ of the total. These hauls only sampled the plankton to a depth of 21 m., or $16\frac{1}{2}$ m. on Station 16, over a total depth of 32 m., and in several instances it was evident from their distribution that considerable numbers of various species were below the range of the nets. Making allowance, however, for these drawbacks, it may be taken that the diagrams do in a general way represent the reactions of the various species to the light intensity under varying conditions.

The diagrams for each station are arranged in a series to show the degree of phototropic reaction of the species represented, except for the few species which are normally surface forms; these are shown separately (Text-figs. 4–8).

All the serial hauls were made when the salinity was relatively high, but there was a considerable difference in the temperature at 10 m. between Station 16 (3rd October, 1928), *ca.* 25·35° C. (the mean between Stn. 15 and Stn. 17) and Stations 62, 65 and 68 (15th June–18th July, 1929), when it was near or below 21° C. and approached the observed minimum. This may account for the apparent differences in vertical distribution between Stations 16 and 68, when the limit of visibility of the Secchi disc was respectively at 10 m. and 9·5 m. On the latter station the number of species with maxima above the Secchi disc limit was much greater, especially as regards the genus *Corycaeus*.

Station 65, the night haul, occupied from 9.0 p.m. to 11.25 p.m., and it is possible that, in accordance with what has been observed in temperate waters, a descent from the surface layers may have been taking place while it was in progress.

The reaction of one surface living species, *Setella gracilis*, to nightfall can be seen in Text-fig. 7. No definite change at night is observable, the night distribution being intermediate between the two daylight hauls of Station 16 and Station 62.

Notes on Species.

Calanus minor (Claus).

This open-sea species was taken inside the reef in small numbers on several occasions between 11th September and 23rd October, 1928, Stations 12 to 22. This corresponds to the time of highest salinity inside the reef and may reasonably be put down to a stray shoal which drifted in and survived. In the serial townettings on Station 16 a very few specimens were found in the nets at 3·1, 11·1 and 16·5 m.

Calanus pauper, Giesbr. (Text-figs. 11, 14, 15, 16 and 17.)

Males, females and stages IV and V were plentiful throughout the year. The immature stages, shown as hatched in the graph (Text-fig. 11) were proportionally most abundant in December, when they amounted to 75% of the stock, falling to a minimum of 18% in January, the stock seemingly having become adult without addition by reproduction before an outburst of breeding in February increased the numbers four times. Females were usually two or three times as abundant as males except towards the end of April and early in May when on four successive stations the males were the more numerous.

In vertical distribution the males, females and younger stages do not show any uniformity, *e.g.* on Station 16 the younger stages were mainly below the Secchi disc limit of visibility while on Station 68, when the Secchi disc limit was at almost the same depth, they were just below the surface.

Undinula vulgaris (Dana). (Text-figs. 1, 11, 14, 15 and 17.)

Taking both size and numbers into account this species occupies the first place in the collections at 3 mi. E. closely followed by *Eucalanus subcrassus*, with *Euchaeta concinna* in the third place. Both Stramin and C.S. nets agree in showing a maximum period on October, November and December. The following table shows approximately the relative proportions of adults and immature stages present each month in the C.S. nets throughout the year, the highest number at any stage being taken as 100. It is possible that the C.S. net takes only a small proportion of the stages I and II actually present. It seems that effective reproduction on a large scale begins in September when the number of adults is very low, reaches its maximum in October, and continues at a diminished rate through January and February. The numbers of adults are highest in November or, according to the Stramin nets, in October.

Table II.—*Relative Numbers of Adults and Copepodite States of* Undinula vulgaris *present in the C.S. nets each month at* 3 *mi. E.*

	♂♀.	v.	iv.	iii.	ii.	i.
August	11	5	12	1	—	—
September . . .	5	11	15	8	5	—
October	26	6	36	68	100	16
November . . .	100	3	19	10	1	+
December . . .	11	14	37	29	5	3
January	10	9	7	7	—	4
February	12	+	26	10	—	—
March	8	6	5	5	—	—
April	6	2	+	8	—	—
May	3	+	1	—	—	—
June	1	2	2	4	—	—
July	12	2	1	1	—	—

The vertical distribution on Stations 16 and 68 when the Secchi disc limit was deep suggests a concentration above the limit; when the limit was nearer the surface, on Station 62, the main body was below it. Only a few specimens were taken in the serial night hauls.

Undinula darwini (Lubb.).

Taken inside the reef, mainly in the Stramin nets, in small numbers only, between August 31st and 15th October. Like *Calanus minor* this is an open-sea species and the coincidence of its occurrence at 3 mi. E. with the period of high salinity is probably significant.

Eucalanus subcrassus, Giesbr. (Text-figs. 11, 15, 16 and 17.)

Almost disappears from the plankton at 3 mi. E. in September, October and November. The Stramin net collections suggest that adults and stage V were scarce in February and March, but this is not borne out by the C.S. net hauls in which they were plentiful. As Stramin net catches of copepods are comparatively small it is probable that the C.S. net results are more reliable.

The vertical distribution is irregular. On Station 62 with Secchi disc limit at 6 m. the majority were below 7 m., but on Station 68 with the limit at 9·5 m. the majority were above 7 m. and many were at the surface as if attracted by the light. On Station 16, not figured, the few specimens present were all below 8 m., and most of them at 16·5 m., the Secchi disc limit being at 10 m. By night (Stn. 65) the bottom net at 20·7 m. had the largest haul.

Paracalanus aculeatus, Giesbr. (Text-figs. 11, 14, 15, 16 and 17.)

The most abundant species at 3 mi. E. From September to January the numbers, though comparatively large, were at a minimum. Males were most numerous in August and September, and were apparently absent in December and January. Immature specimens were present throughout the year. The relative proportions of adults and immature varied irregularly from station to station throughout the year.

The vertical day distribution on Stations 16, 62 and 68 appears to be governed by the light penetration, the highest numbers being just below the Secchi disc limit, the only exception being the males on Station 68, which were above the limit though not reaching the surface ; on the other two stations the males , females and immature all agreed closely in vertical distribution. The night distribution on Station 65 was approximately uniform from the surface to 21 m.

Paracalanus parvus (Cls.). (Text-figs. 11, 14 and 16.)

The highest numbers occur in August, falling off gradually to a minimum in February, with a temporary scarcity in September. They remain low till the beginning of August.

Station 16 was the only daylight station on which the numbers were high enough to show the vertical distribution, which was almost identical with that of *P. aculeatus* for all stages, though, in the night distribution on Station 65, it differs considerably from that species, neither males nor females reaching the surface. The males are concentrated between 4 and 8 m. and the females uniformly between 8 and 20 m.

Acrocalanus gibber, Giesbr. (Text-fig. 11.)

Occurred at intervals in every month in small numbers on 34 out of 52 stations at 3 mi. E. The difficulty of distinguishing between the immature specimens of *A. gibber*, *A. longicornis* and *A. gracilis* makes any numerical estimate of their relative abundance of little value. *A. longicornis* occurred on 21 stations in every month but August, and *A. gracilis* on 21 stations in every month. In Text-fig. 11 is shown the distribution in time of the total of all three species, including immature specimens.

Clausocalanus furcatus (Brady). (Text-figs. 11 and 14.)

Occurred in every month except May on 17 out of 52 stations, most frequently in September and October, but except in these months the numbers were small.

Only on Station 16 were there sufficient numbers to show the vertical distribution. Probably not a true reef species.

Clausocalanus arcuicornis (Dana). (Text-figs. 11, 16 and 17.)

Total numbers not as high as for *C. furcatus* but more uniformly distributed on 31 out of 52 stations. There is a distinct maximum in September and October with indications of a secondary maximum in February and March.

The vertical distribution is shown for two daylight stations (Stns. 62 and 68) Text-figs. 16 and 17. On them the species evidently extends below the depth sampled. By night the highest numbers are at 8 m.

Euchaeta concinna, Dana. (Text-figs. 11, 14, 15, 16 and 17.)

Although only 13th in abundance its total, owing to its large size, would almost equal in bulk that of *Undinula vulgaris* and *Eucalanus subcrassus*, and for four months, May to August, it was the most noticeable species at 3 mi. E. From October 22nd to May 7th it was practically absent from the C.S. nets. A few females were seen in February and occasional immature specimens in March and April, but from May 18th adults and immature appeared in increasing numbers to reach a maximum in July, which was observed both at the beginning and at the end of the Expedition. The stramin nets, which take adults and stage V, gave corresponding results except for an unexplained apparent scarcity in June ; possibly there was an actual scarcity of the larger stages, the numbers of which in two C.S. net hauls at the end of May and early in June were low.

The hauls showing vertical distribution indicate that except at night none of the stages reach the surface, the youngest stages (Stns. 16 and 68) lying deepest in the water. At night females appear to be uniformly distributed from the surface to at least 20·7 m. ; males and stage V stop short of the surface while stages I–IV are mostly congregated about 8 m., a few of them coming to the surface.

Centropages furcatus (Dana). (Text-figs. 12 and 15.)

Present throughout the year with a minimum in October, gradually increasing to a maximum in April.

Only on Station 62 were there sufficient specimens to show the vertical distribution, with a maximum at 7·5 m. and a downward extension to below 21 m. On Station 16 the few specimens present were all below 8 m.

Centropages orsinii, Giesbr. (Text-figs. 12 and 14.)

More numerous at 3 mi. E. than appeared on a first examination of the samples. Except for those in the serial hauls on Station 16 on 3rd October all were taken between 6th November (Stn. 24) and 10th July (Stn. 65) and 93% from December to March.

The small numbers examined from the serial hauls on Station 16 were almost all within the range of Secchi disc visibility at 10 m. A very few specimens taken on the night hauls were all in the surface net. It is probable that this species should be regarded as being mainly a surface form.

Pseudodiaptomus aurivillii, Cleve.

Two males, length ·95 mm., and two females, length 1·2 mm., were found in an additional sample examined from the C.S. net of 6th November 1928 (Stn. 40). The fifth feet of the male agree in most details with A. Scott's figure (I. C. Thompson, and A. Scott, Ceylon Pearl Oyster Fisheries, 1903, Suppl. Repts., No. VII). The cephalothorax in both sexes is similar, but the furca of the male is proportionally much shorter than that of the female.

Temora discaudata, Giesbr. (Text-fig. 12.)

Absent from 3 mi. E. in July, August and September and very scarce in October and June. The maximum is from January to April, corresponding to the period of lowest salinity.

Temora turbinata (Dana).

A few specimens were taken inside the reef on 7 stations out of 14 taken in January, February, March and April, the period of the maximum for *Temora discaudata*.

Candacia discaudata, A. Scott. (Text-figs. 12, 14, 15 and 16.)

Nearly always present in small numbers throughout the year at 3 mi. E., both in the stramin and C.S. nets, and occasionally plentiful at irregular intervals in the C.S. nets.

The serial townets by day (Stns. 16 and 62) show the bulk of both adults and young low in the water, at 16 m. or lower. By night on Station 65 the main body of adults was much higher, at about 8 m., with a considerable proportion reaching the surface. Immature stages were absent on Station 65.

Calanopia elliptica (Dana). (Text-figs. 12, 15 and 16.)

Present inside the reef throughout the year but scarce from August to December, and more plentiful from January to July. The largest take was on 20th April (Stn. 54).

In the serial townettings the adults were well below the Secchi disc limit by day, but the immature, on Station 62, when they alone were present, were in part at or just below the surface and in part deep in the water at 16·5 m. By night the main body of adults were at 8 m., a small proportion reaching the surface.

Calanopia aurivillii, Cleve. (Text-fig. 12.)

The period of plenty, the end of January to the end of April, corresponds to that of *C. elliptica* and for those months the numbers of both species were about equal, but for the rest of the year *C. aurivillii* is almost absent and none was seen from 12th September to 21st January. It did not occur in the serial townets.

Labidocera acuta (Dana). (Text-fig. 12.)

The period of occurrence, from 19th December to 10th July, is clearly marked in the C.S. nets and is confirmed by the stramin net catches, which however, usually took very few specimens. In only one Stramin net haul was it common. The numbers in the C.S. nets varied very widely. Though the numbers were relatively small the large size of the individuals, which were mainly adult, made them a very prominent feature. Its last appearance was a few specimens in the surface net of the night serial townets on Station 65.

Labidocera acutifrons (Dana). (Text-fig. 4.)

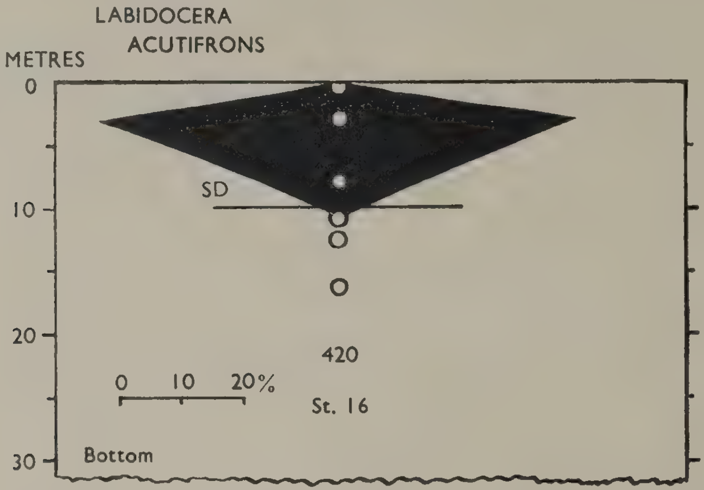
Only taken on 4 stations between 26th September and 15th October, very few specimens.

In the vertical nets on Station 16 its maximum, 74%, was at about 3 m.; none was below the Secchi disc limit and only one was found in a sample of $\frac{1}{10}$ of the surface catch.

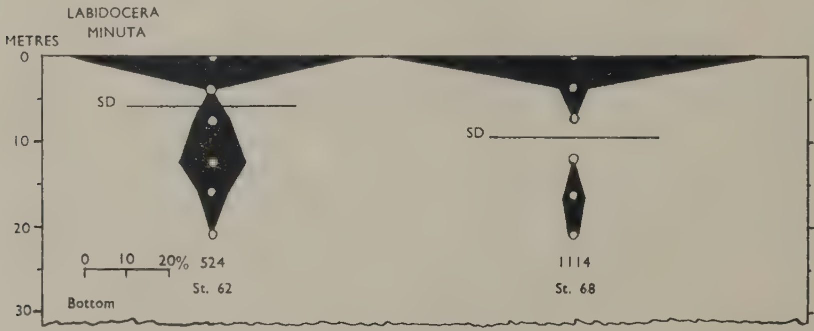
Labidocera minuta, Giesbr. (Text-figs. 5 and 12.)

More plentiful for a limited period than the first examination of the samples suggested. After a few specimens taken on single stations in October and November it was moderately common at intervals up to the end of May, the period of highest temperature.

In the serial townettings on Station 68 over 85% were in the surface townet and the remainder were possibly taken by the deeper nets while they were being hauled. On Station 62 the numbers in the deeper hauls, 30%, were too high to be accounted for in this way.



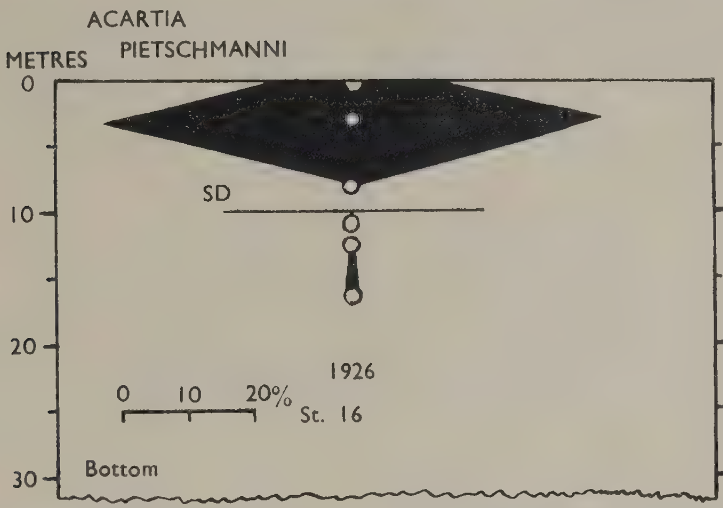
Text-fig. 4.—Vertical distribution in daylight of *Labidocera acutifrons* at 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.



Text-fig. 5.—Vertical distribution in daylight of *Labidocera minuta* at 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.

Acartia peitschmanni Pesta. (Text-fig. 6.)

Further samples, available later from Station 16, the only station inside the reef on which it was found, gave sufficient specimens to allow of a diagrammatic representation (Text-fig. 6) of its vertical distribution. It appears to be definitely concentrated by day just below the surface.



Text-fig. 6.—Vertical distribution in daylight of *Acartia pietschmanni* at 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.

Acartia pacifica, Steuer. (Text-figs. 13, 15, 16 and 17.)

For two months, July and August, it was moderately common at 3 mi., E. but except for a few stations in February and March it was absent or very rare for the rest of the year. The serial daylight townettings in which it was adequately represented (Stns. 62 and 68) gave the anomalous result that when the Secchi disc limit was shallow there was a scarcity just below the surface, but when it was deep the numbers just below the surface were high. In the night hauls a moderate proportion reached the surface though the majority were deep in the water at 20·7 m.

Acartia australis, Farran. (Text-fig. 13.)

Only found at 3 mi. E. between 23rd October and 15th June, nearly 80% having been taken in November and December. This is definitely an oceanic species and it is probable that a shoal drifted in when the salinity was at or near its maximum.

Acartia negligens, Dana. (Text-fig. 13).

This is a widespread species in the open sea and was common at 3 mi. E. for a short period, from mid-August to mid-October, doubtless due to an incursion from outside.

Tortanus gracilis (Brady). (Text-figs. 13, 15 and 16.)

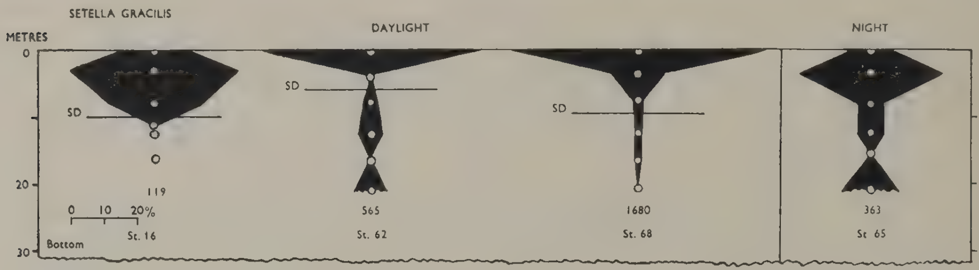
Has a clearly marked seasonal distribution, being absent from August to December, increasing in numbers from January to April and decreasing more gradually till July. More plentiful than appeared from the examination of small samples.

The serial townettings suggest that it is sensitive to light penetration. On Station 62 with the Secchi disc limit at 6 m. the main body of males and females was deep in the water, at 16–21 m., and probably deeper, but with a considerable number of immature specimens (not figured) and some adults just below the Secchi limit. On Station 68 (not figured), with a deep Secchi disc limit at 9½ m., there were very few at any stage and none above 12 m. In the night hauls at Station 65 there was a large concentration actually at the surface, mainly of adults ; probably the most marked instance of upward migration.

Setella gracilis, Dana. (Text-figs. 7 and 13.)

Occurred in small numbers throughout the year with marked increases in December, April and June, probably due to uneven horizontal distribution.

This is almost entirely a surface form as is shown by the serial townettings (Text-fig. 7) in which it was scarce. On Station 16 the few specimens present were at the surface, 3 m. and 8 m. On Station 62 65% were at the surface, and on Station 68 75%. In the night hauls on Station 65 a concentration at 3·8 m. caused a partial desertion of the surface.



Text-fig. 7—Vertical distribution in daylight and in the dark of *Setella gracilis* at 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.

Oithona plumifera, Baird. (Text-figs. 13, 14, 15, 16 and 17.)

For five months, November to March, the numbers are comparatively low. They then increase to a period of abundance in July, August, September and October. The change from abundance to scarcity appeared to occur between 15th October and 22nd October with a rising temperature and falling salinity.

The vertical distribution as shown by the serial hauls suggests an avoidance of the upper layers, independent of the clearness of the water, except at night when the distribution from just below the surface to 21 m. was fairly uniform.

Oithona rigida, Giesbr.

Occurred on 17 out of 51 stations at intervals throughout the year, but usually only with two or three specimens in the samples examined.

Oncaea clevei, Fruchtl. (Text-figs. 13, 14, 15, 16 and 17.)

There are suggestions of two not very clearly marked maxima, in July–August and March–April, with a minimum in November.

Judging by the serial hauls it appears usually to avoid the surface layers except at night, when, on Station 65, the maximum concentration was at 8 m. On the daylight serial stations the highest numbers were taken in the lowest net fished, and the maximum concentration was probably deeper still. The drop in numbers in the February catches may possibly be due to the exceptional light penetration which was indicated by the Secchi disc and not to decrease in the stock.

Corycaeus lubbocki, Giesbr. (Text-fig. 13 and 14.)

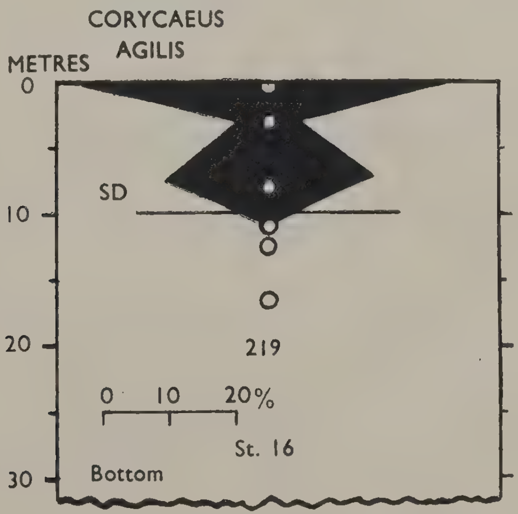
Scarce from December to June. In July it suddenly increases in numbers and is plentiful from August to October, the numbers falling off in November. The high numbers in July were noted both at the beginning and at the end of the Expedition.

The numbers in the serial townets were too few to illustrate the vertical distribution except on Station 16, where both males and females showed increasing numbers from 8 to 16 metres, the lowest depth fished.

Corycaeus erythraeus, Cleve. (Text-figs. 13, 14, 15, 16 and 17.)

Present throughout the year in varying numbers on almost every station, the average numbers showing an increase from a minimum in September to a maximum in March and April and then falling off with a slight revival in July and August.

The serial stations gave inconsistent results. On Station 16 practically all were below the Secchi disc limit at 10 m., but on Station 68 with the Secchi disc limit at 9·5 m. the bulk were just below the surface, well above 10 m. Conditions on Station 62 were intermediate and resembled the night distribution as shown by Station 65.



Text-fig. 8.—Vertical distribution in daylight of *Corycaeus agilis* at 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.

Corycaeus agilis, Dana. (Text-fig. 8.)

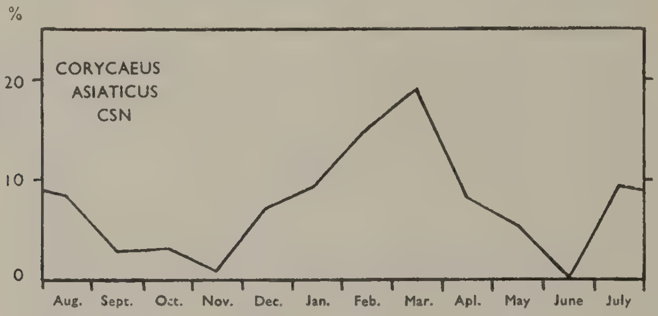
Sporadic occurrences at 3 mi. E., one or two specimens in the sample examined, each month from June to October.

In the serial hauls on Station 16 it was found to a depth of 8 m. On the three other serial stations the few specimens present were all between the surface and 4 m.

Corycaeus asiaticus, F. Dahl. (Text-figs. 9, 14, 15, 16 and 17.)

Scarce though usually present from September to November, rising to a plentiful maximum from mid-January to the end of March. Moderately common for the rest of the year.

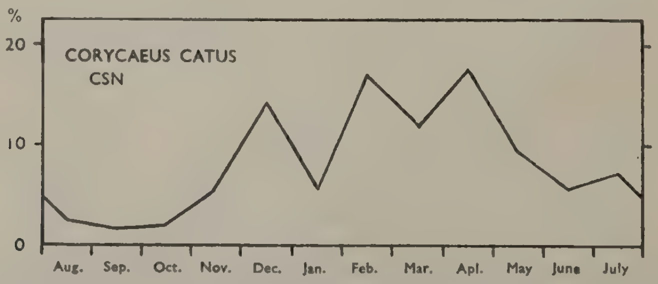
The vertical distribution, as shown by the rather small numbers available, is very irregular as regards both males and females.



Text-fig. 9.—Average catches of *Corycaeus asiaticus* for each month at 3 mi. E. of Low Is., expressed as percentages of its total annual catch. Coarse silk net.

Corycaeus catus, F. Dahl. (Text-figs. 10, 15, 16 and 17.)

Present throughout the year with a minimum in August, September and October, increasing to a maximum in February and decreasing gradually till July. The serial townets show the same irregular distribution as in the other species of *Corycaeus*. By night the distribution was lower in the water than by day.



Text-fig. 10.—Average catches of *Corycaeus catus* for each month at 3 mi. E. of Low Is., expressed as percentages of its total annual catch. Coarse silk net.

Corycaeus speciosus, Dana.

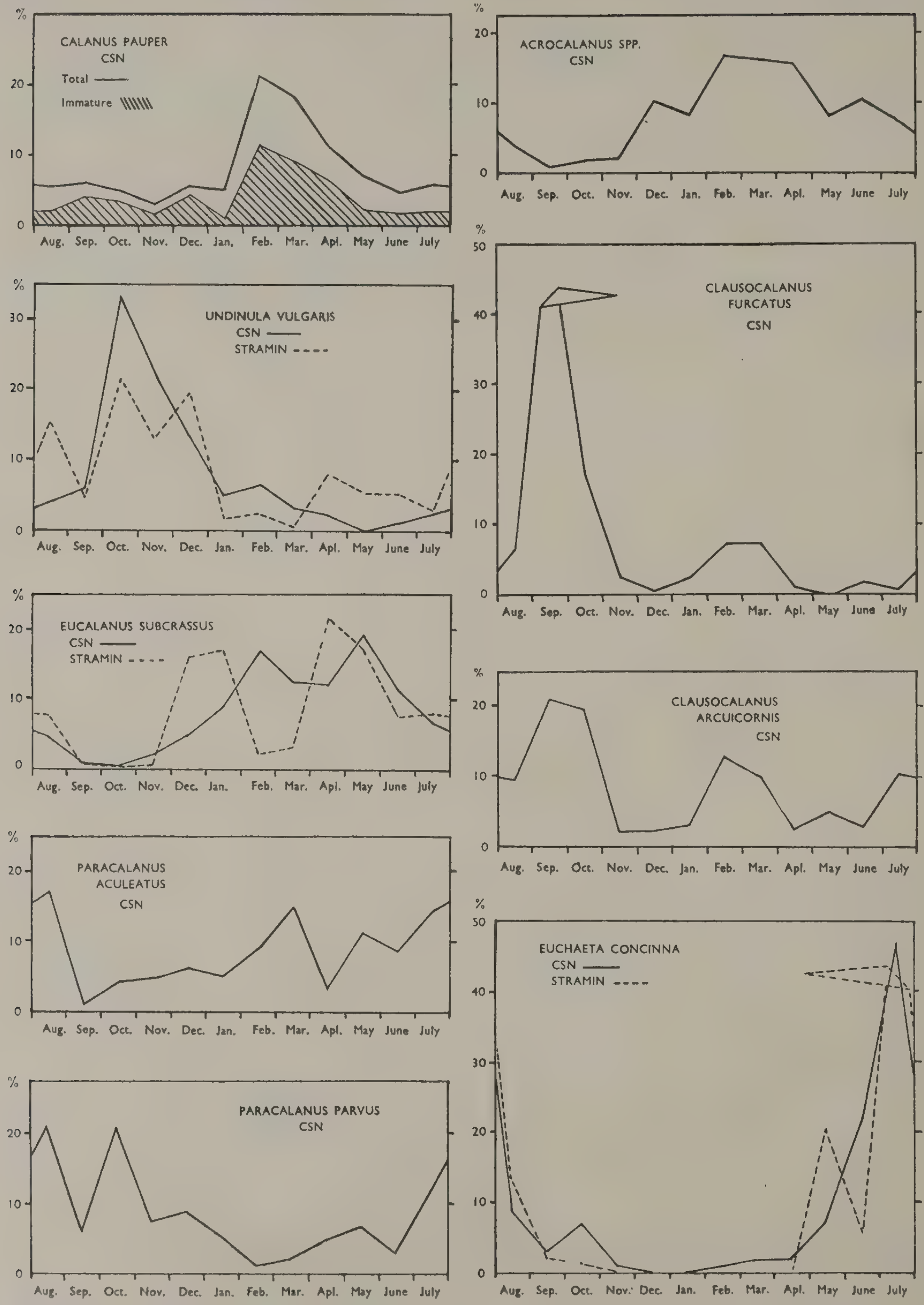
Not seen in November, December or May. Present in small numbers on 3 stations in August and on 4 in September, with single records for the remaining months. It should probably be regarded as an open sea rather than as a coastal form.

Corycella gibbula (Giesbr.).

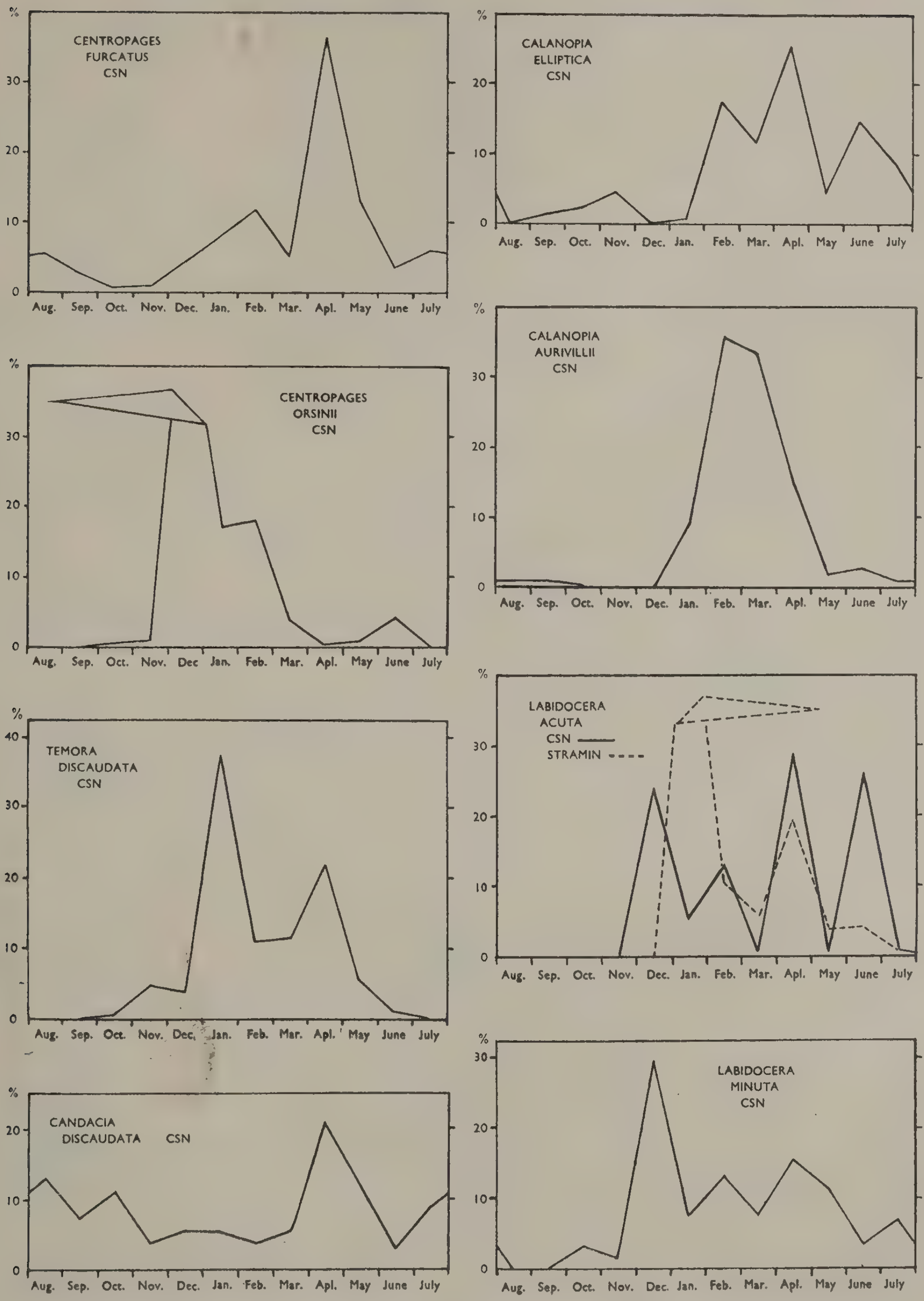
Scarcer than the first examination of the samples indicated. A few specimens were taken on twelve out of 50 gatherings from 3 mi. E. The highest numbers were on Stations 1 to 3, 27th July to 4th August. Both this species and *C. concinna* are too small to be taken normally by the C.S. nets.

Corycella concinna, Dana.

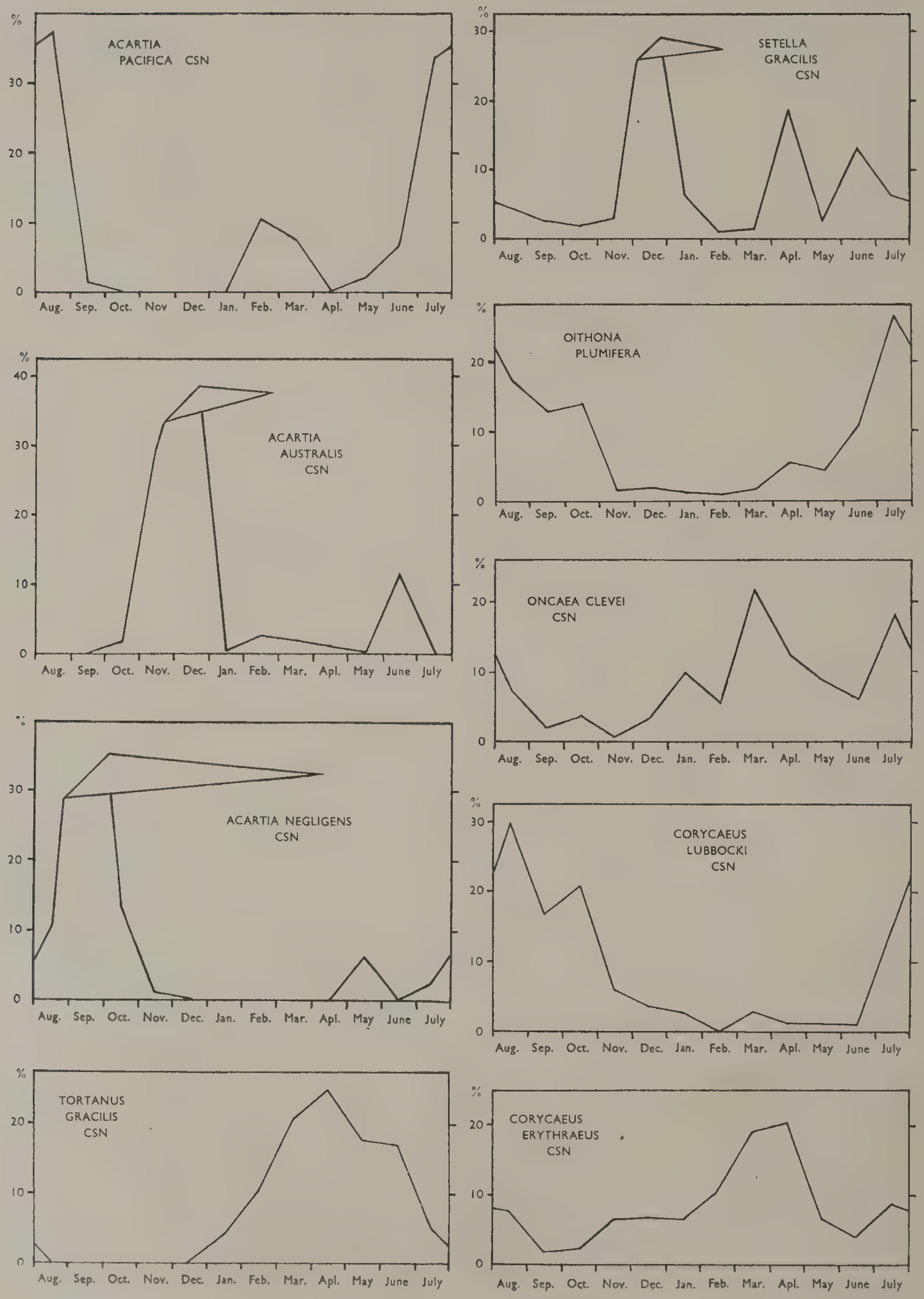
Taken on ten out of 50 gatherings from 3 mi. E., five of them between 30th July and 11th September.



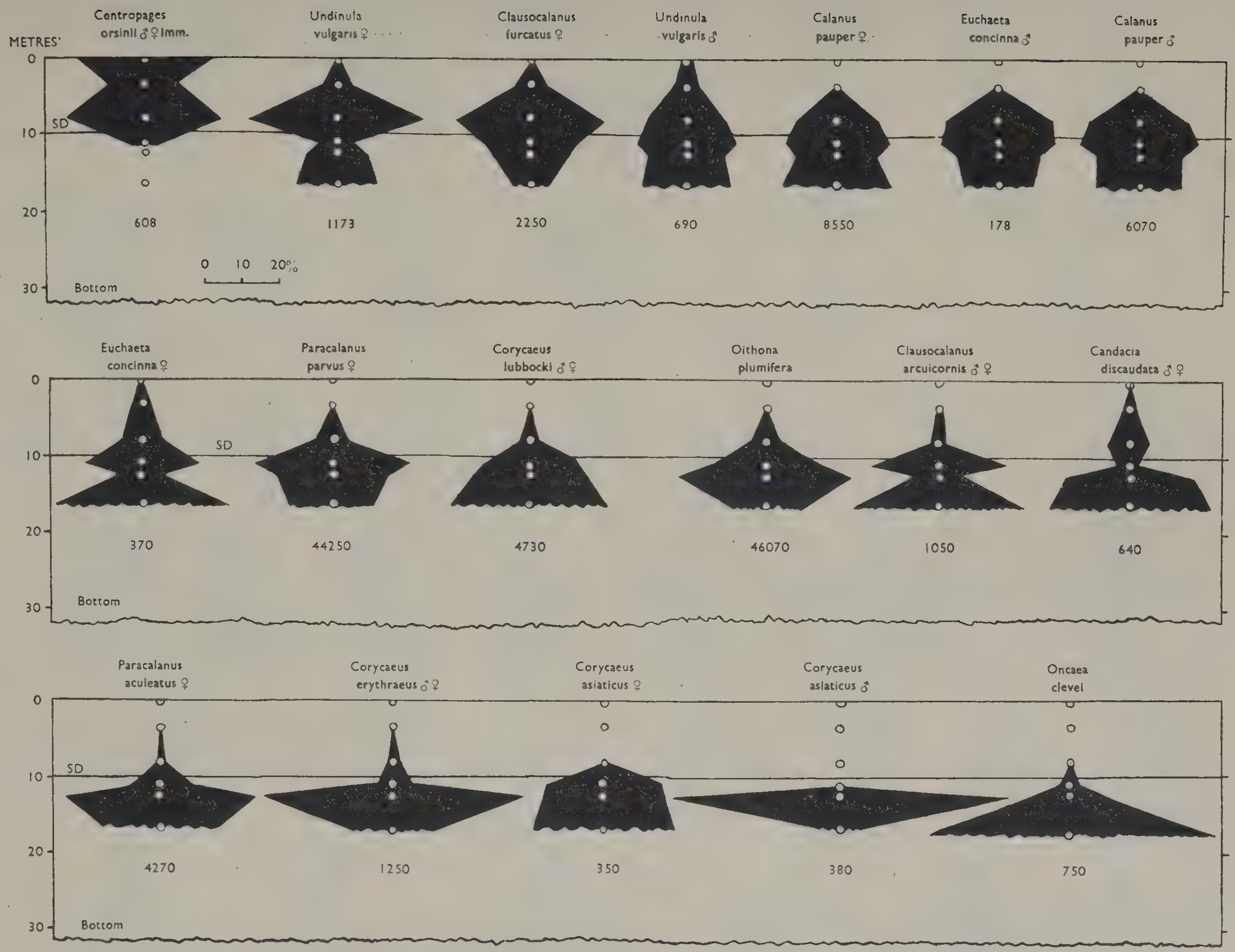
Text-fig. 11.—Average catches of individual species of copepods for each month at 3 mi. E. of Low Is., expressed as percentages of their total annual catches. (Some of the high peaks in this figure and the next are shown as if folded over, to economize space.) CSN., Coarse silk net.



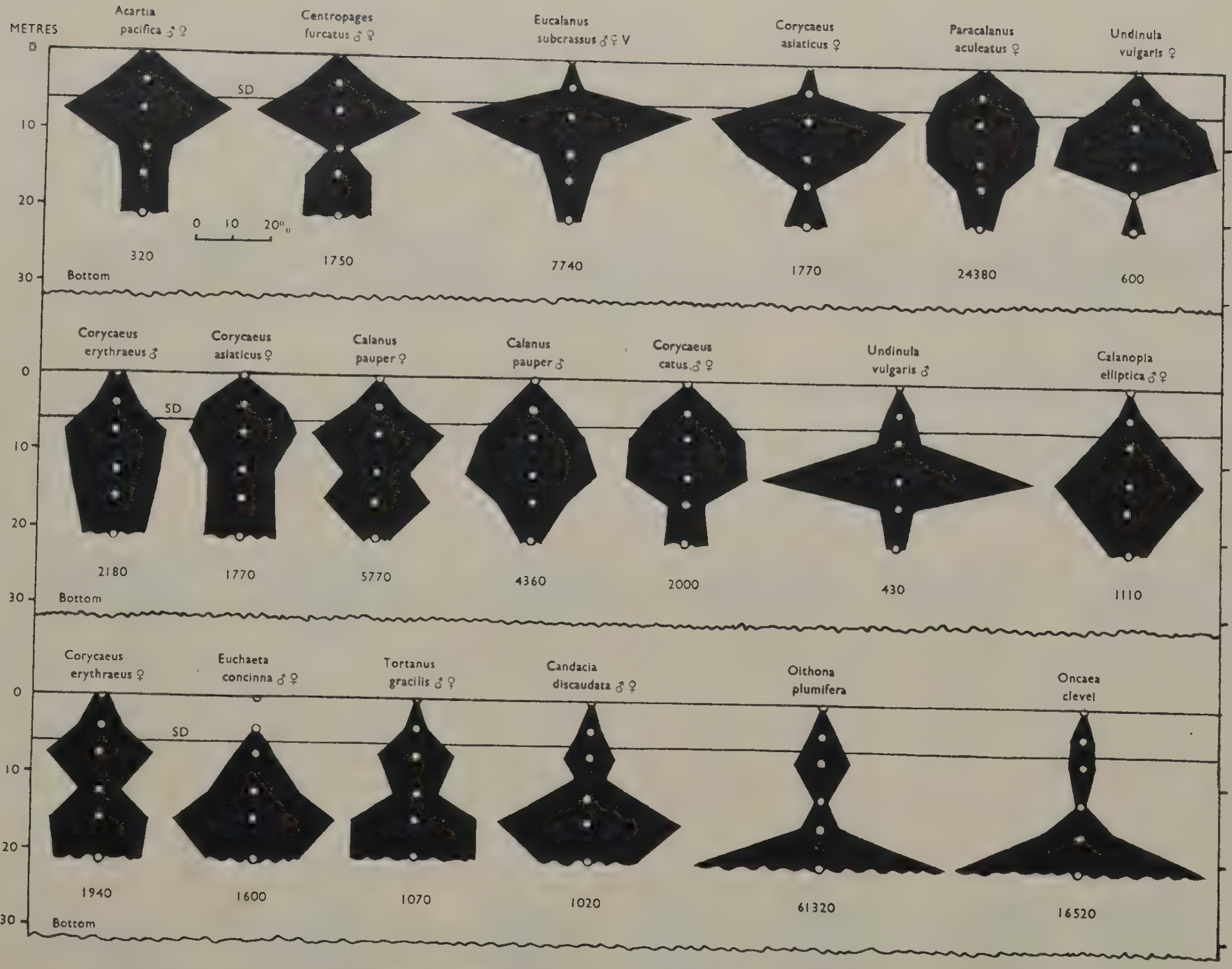
Text-fig. 12.—Average catches of individual species of copepods for each month at 3 mi. E. of Low Is., expressed as percentages of its total annual catches. CSN., Coarse silk net.



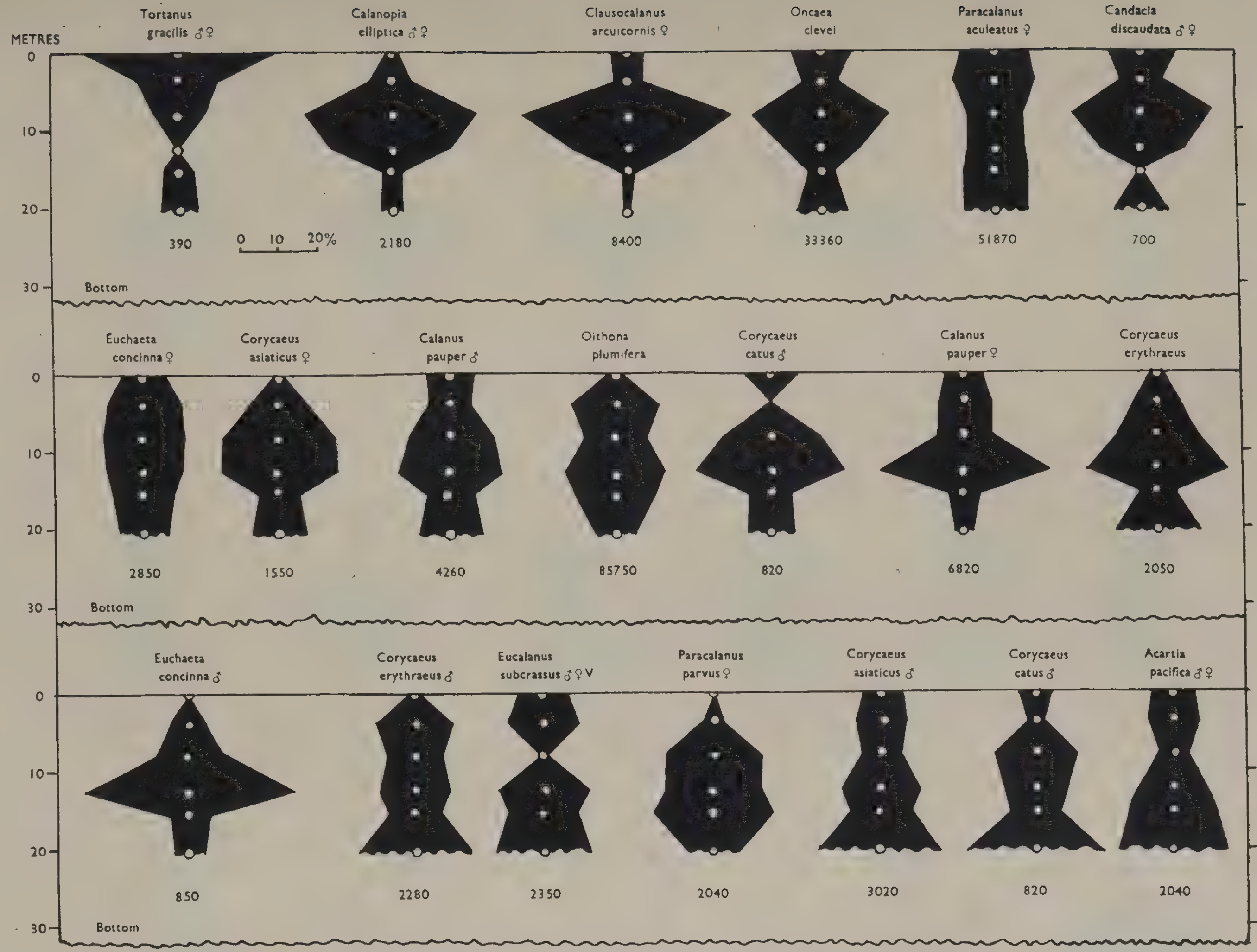
TEXT-FIG. 13.—Average catches of individual species of copepods for each month at 3 mi. E. of Low Is., expressed as percentages of their total annual catches. CSN., Coarse silk net.



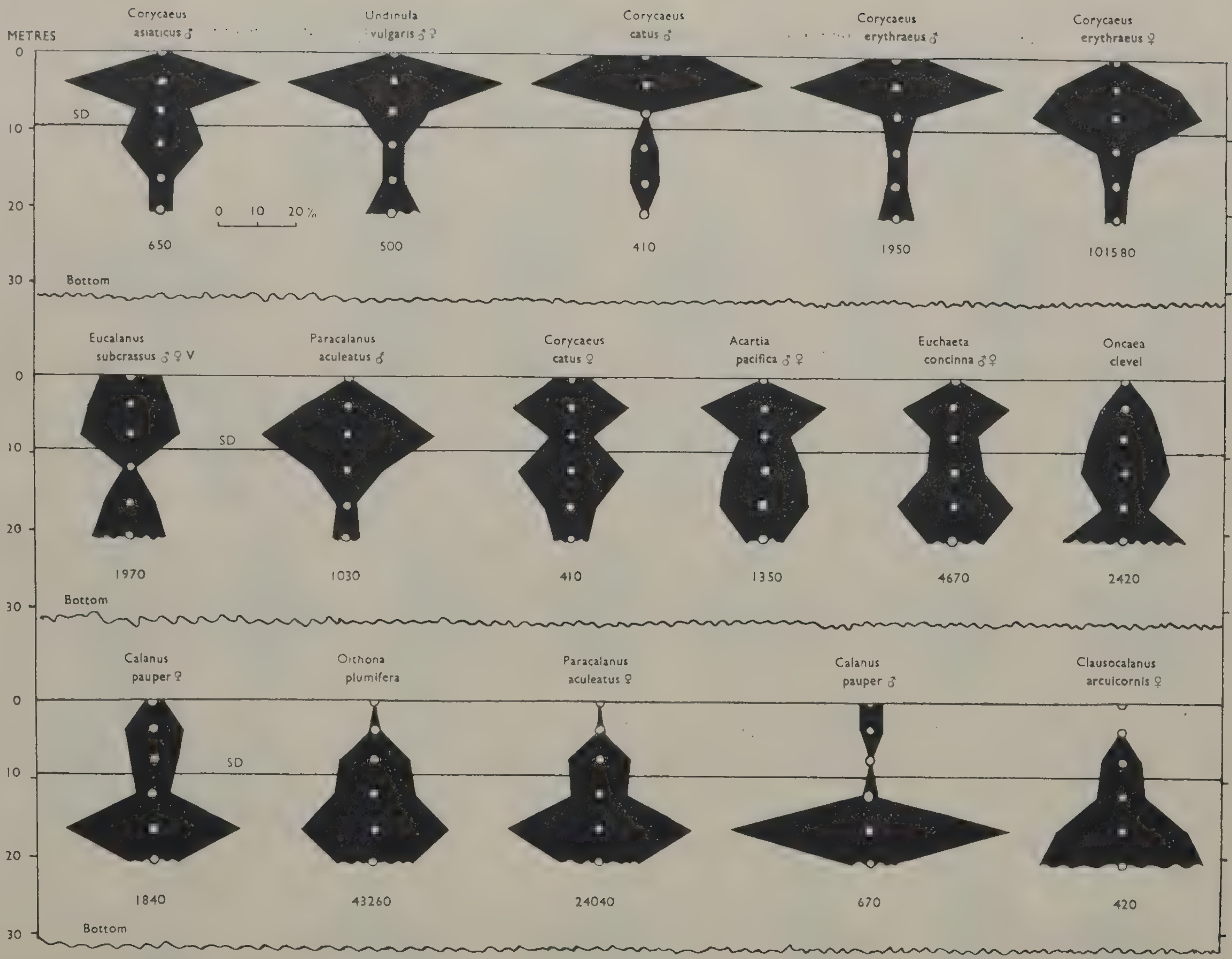
TEXT-FIG. 14.—Vertical distribution of copepods on Station 16 (3.x.28) 10.13 am. to 12.27 p.m., 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.



TEXT-FIG. 15.—Vertical distribution of copepods on Station 62 (15.vi.29) 11.20 a.m. to 1.45 p.m., 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.



TEXT-FIG. 16.—Vertical distribution in darkness of copepods on Station 65 (10.viii.29) 9.0 p.m. to 11.25 p.m. 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which the hauls were made. The figures below each diagram are the estimated totals of the catch.



TEXT-FIG. 17.—Vertical distribution of copepods on Station 68 (18. vii. 29) 10.30 a.m. to 12.55 p.m. 3 mi. E. of Low Is. Coarse silk townet. S.D., Secchi disc reading. The circles and white dots indicate the average depths at which hauls were made. The figures below each diagram are the estimated totals of the catch.

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